TITLE

Testing the constrained action hypothesis - the impact of internal and external cues on vertical jump and change of direction performance in trained and sedentary populations

AUTHOR

Birnie, Ewan

DATE DEPOSITED

2 September 2016

Testing the constrained action hypothesis – the impact of internal and external cues on vertical jump and change of direction performance in trained and sedentary populations.

Ewan Birnie

Supervisors – Daniel Cleather and Emily Cushion

27th June 2016

This Research Project is submitted as partial fulfilment of the requirements for the degree of Master of Science, St Mary's University.

Table of Contents

List of Figures

List of Tables

Acknowledgements

I would like to thank Dr. Daniel Cleather for his assistance and guidance throughout completion of this piece of work.

Abstract

The impact of internal (INT) and external (EXT) cues on vertical jump (VJ) and change of direction (CoD) performance was examined in contrasting groups. Fourteen subjects participated, divided into two groups. Group one (n=8, age:27±5 years; body mass 78.4±8.0kg) were experienced athletes. Group two (n=6, age:27±4 years; body mass 74.7±13.6kg) were sedentary. Subjects performed 9 VJ and 12 CoD trials following INT, EXT and neutral (CONT) cues. Ground reaction forces were gathered by force plates for all performances. No interaction between experience and condition in VJ was found ($F(10,3)=4.396$; $p=0.13$). Comparisons revealed velocity, power and impulse were greater in EXT compared with INT ($p \leq 0.05$) for all subjects, with no difference for height or force ($p>0.05$). An interaction between experience and condition was found for time to maximum force on left CoD turns ($F(2,24)=4.118$; $p=0.02$), with it significantly longer for sedentary performers. Comparisons for all subjects revealed EXT produced quicker trials than CONT ($p<0.01$). CONT produced lower impulse than INT ($p=0.01$). Time to maximum force on left turns was faster in EXT than INT ($p=0.03$). The study supports the constrained action hypothesis, but questions the role of automaticity. Instead, it would beneficial to examine cognitive demand, considering additional influencing factors.

Key Words: coaching practices, verbal instructions, attention focus

Testing the constrained action hypothesis – the impact of internal and external cues on vertical jump and change of direction performance in trained and sedentary populations.

Research investigating vertical jump (VJ) (Ford et al., 2005; Wulf & Dufek, 2009; Wulf, Dufek, Lozano, & Pettigrew, 2010) and change of direction performance (CoD) (Porter, Nolan, Ostrowski, & Wulf, 2010) suggests the use of cues focussing attention on external (EXT) factors positively impact performance compared with cues generating internal (INT) focus. However, universal application of this effect appears assumptive, as highlighted by a range of counter arguments to currently published research (Maurer & Zentgraf, 2007; Mullen, 2007; Toner & Moran, 2007; Weigelt, Schack, & Kunde, 2007; Wrisberg, 2007).

A common theme in these counter arguments is the lack of consideration given to individual differences between subjects (McPherson, 2000; Perkins-Ceccato, Passmore, & Lee, 2003). Whilst differences are potentially numerous, a factor of importance to the coach is prior experience in the chosen activity. The majority of work examining this area has used untrained populations, whom have limited experience; largely overlooking that experience of the athletic population may impact upon cue effectiveness (Wulf and Su, 2007).

Much research refers to the constrained action hypothesis (CAH) as an explanation for improved outcomes achieved in the presence of EXT cues (Wulf, 2007). This theory suggests that INT cues interfere with automaticity of performance by inhibiting coordination, with EXT cues permitting the performer to exert control subconsciously, allowing a degree of 'self-organisation' (Wulf, 2007). Wulf (2007) describes self-organisation as a state in which little attention to technical aspects of performance is required, with a successful outcome generated. This has proven difficult to quantify, although Lohse, Sherwood, and Healy (2011), Vance, Wulf, Tollner, McNevin, and Mercer (2004) and Wulf et al. (2010) identified that electromyographic activity of muscles decreases with provision of EXT cues, suggesting movement becomes more economical, and self-organisation is present. Wulf (2007) proposes that there is a link between the muscular activity observed in a given movement, and the degree of self-organisation present. It is suggested that greater muscular activity indicates that an individual is exerting conscious control over specific technical components, whereas less muscular activity is associated with subconscious control. However, this theory is yet to be supported by research, and appears to be a substantial limitation of the CAH.

The cognitive theory of motor development (Fitts & Posner, 1967) assists in identifying how experience differences may impact upon performance automaticity. The model provides three stages of skill development: cognitive, associative and autonomous. This theory proposes that as learners become more skilled, they move through each stage, ultimately leading to an autonomous performance. Each stage is characterised by changes in cognitive demand and sources of input during performance, with those in earlier stages of learning faced with larger cognitive demands, exerting conscious control over movements, with experienced performers utilising subconscious control. This theory has been supported by research in a range of learning situations (Tenison & Anderson, 2015; O and Hall, 2009).

Wulf (2007) suggests that inexperienced performers in the cognitive or associative stages of learning are likely to focus internally during performance of an unfamiliar skill, whereas experienced performers will be largely autonomous and therefore afford attention to external stimuli due to this skill familiarity. It is debatable as to whether the provision of an EXT cue would have a similar impact on groups of different experience levels, given focus preferences will likely vary. Furthermore, as experienced performers are likely to be more automatic, interference with this automaticity through the use of INT cues may be of greater detriment than it would be to those where automaticity is lacking. Despite this apparent flaw in the hypothesis, there is limited research investigating this.

Weigelt et al. (2007) and Wrisberg (2007) highlighted that many actions investigated in the currently published research involved EXT targets, such as basketball shooting or putting in golf. They suggest that it is unsurprising that success is higher with the provision of EXT cues in performances that are measured by the outcome in relation to an EXT target. Its logical that if subjects focus on the performance measure during execution, the outcome will be better than when focussing on something other than this. Therefore, the selection of VJ and CoD within this study removed obvious external targets, allowing a comparison to be drawn in which EXT conditions could be created without the need to draw attention to a specific outcome. This allowed a fairer comparison between INT and EXT conditions, as whilst both cues had a different focus of attention, they focused on the same part of the performance. This has not been the case in previous work examining the CAH.

Finally, the chosen performance measures were of moderate complexity, meaning both trained and sedentary populations were capable of executing the skills. Skills that were perhaps too simple may have been insufficient in generating differences in performance automaticity between groups, and skills that were too complex would have potentially placed sedentary subjects in a situation where successful performance was not achieved, or injury risk was high.

It is hypothesised that EXT cues will generate optimal performance in both tests, in both groups. INT cues are expected to hinder performance in both groups, but to a greater extent in the trained population. The rationale for this is based on the CAH. The trained population are likely to be at an autonomous stage of development in both tests, with a focus placed on INT aspects likely to interrupt normal performance. As VJ is likely to be a more familiar skill to the sedentary population than CoD, and therefore more automatic, it is hypothesised that INT cues will be more detrimental to VJ than CoD. It is anticipated that sedentary performers will demonstrate an INT focus preference during control (CONT) trials, with trained performers favouring an EXT focus, according to the CAH.

Methods

Experimental Approach to the Problem

This study aims to establish if the pattern of positive effect associated with EXT cues could be applied equally to experienced and sedentary populations. This will be achieved through completion of the following aims.

- Compare the impact of INT and EXT cues on VJ and CoD performance in experienced and sedentary populations.
- Establish how each population prefer to focus attention during VJ and CoD performance in the absence of verbal instruction.
- Measure the impact of cues on kinetic and kinematic features of VJ and CoD performance.

The study utilised a within-subject repeated measures quantitative design, requiring the creation of two groups: trained and sedentary. Comparing the impact of the cues on each group allowed the CAH to be tested as these groups in theory were at opposite ends of Fitts and Posner's motor development model, and as such had differing levels of automaticity.

Subjects

A total of fourteen subjects participated, with subjects divided into two groups, depending upon activity level and experience. Suitability for participation and subject grouping was determined through completion of physical activity readiness and exercise history questionnaires. Group one participants (n=8, age: 27 ± 5 years; height: 1.76 ± 0.03m; body mass 78.4 ± 8.0 kg) had experience in VJ and CoD performance. Participants were recruited from local teams in sports where these skills are central to performance and would be trained regularly. Five participants competed in soccer, two in netball, and one in Australian Rules football. Group one subjects had participated in their sport and associated training frequently (average of >3 times per week) for a minimum of 3 years. Subjects had to have engaged in both agility/CoD and plyometric training for a combined period of 6 months in this 3-year period.

Group two participants (n=6, age: 27 ± 4 years; height: 1.72 ± 0.05m; body mass 74.7 ± 13.6 kg) were sedentary, and had no VJ and CoD experience. Sedentary was defined as not meeting the government physical activity guidelines of a minimum of thirty minutes of activity per day, over the past year. Additionally, subjects had no consistent participation at any time in the identified sports or any other sport that may require CoD or jumping. This group had never participated in any plyometric or CoD training. Group two subjects were recruited from the student base of FIA Fitnation, Sydney, Australia. There was no significant difference in either height or body mass between the two groups ($p>0.05$). Participants in both groups were injury free in the previous 6 months, and aged 18-35 years. Ethical approval was obtained from the Ethics Committee of St Mary's University, London, Twickenham prior to study commencement.

Procedures

Subjects were provided with an information sheet and informed consent form, outlining all procedures, pre-test requirements, data storage and rights to cease participation. On review of these documents and the provision of consent, subjects were permitted to progress to testing if all requirements were met.

Subjects attended three testing dates no less than 48 hours apart, and no more than seven days apart. Sessions were forty minutes in duration, with subjects tested in three conditions: CONT, INT and EXT. In testing session one, subjects performed in the CONT condition for both tests to minimise potential impact of prior cues. In sessions two and three, subjects performed in either INT or EXT conditions, the order of which was determined randomly, with the subject picking one of two envelopes containing the possible conditions. Subjects were unaware of the conditions prior to participation. In each condition, three VJ tests were performed with two minutes rest between jumps, and four 5-10-5 Pro-Agility runs with three minutes rest between each performance. The VJ tests were performed first in each of the testing sessions. The researcher deemed that the dynamic nature of CoD testing had greater potential to produce fatigue that may negatively impact upon subsequent performances. Whilst steps were taken to negate this effect in the rest periods provided, it was felt that placing jumps first in testing session could contribute further to test reliability.

At the beginning of testing session one, subject height was measured with a stadiometer (SECA, 2015). The subject's dominant foot was recorded to inform analysis of CoD. This was determined by the inclusion of a question of foot preference within the exercise history questionnaire. Prior to each session, subjects completed a standardised warm up as shown in Table 1.

Table 1.

Pre-Test Warm Up

Exercise	Sets	Reps
Walking lunges	2	10
Walking toe touch	2	10
Knee lifts	2	10
Twisting lunges	2	10
Pivot and squat	2	10
High knees	2	10
Heel flicks	2	10
Vertical Jump	1	5
10m shuttle runs	2	4

Instrumentation. For each jump and CoD performed, ground reaction forces (GRF) were recorded in Newtons (N) at a rate of 1000 Hertz (Hz) through two force plates (PASCO Scientific, PASPORT PS-2141 [Force plates]. Roseville, CA.). Plate stability was ensured through manipulation of adjustable feet. Plates were connected to a laptop with PASCO PS-2100A USB links with PASCOcapstone™ (PASCO Scientific, 2015) display and analysis software used to gather data.

Vertical Jump. Force plates were placed side by side on a flat and hard surface. GRF was recorded on both force plates from prior to jump performance until completion of landing. The forces gathered from each plate were summed to provide overall GRF for each jump. Data was entered into an Excel spread sheet for completion of the integration method, determining the subject's weight, mass, jump height, impulse, velocity and power, from which maximal values were obtained. The integration method is a mathematical model that makes use of the trapezium rule. The equations for this model are shown in Figure 1 below.

Figure 1. Integration Method

Force data gathered. Subject weight (N) calculated by:
Average Force 0.001 to 1.000 seconds*

↓

Net force (N) calculated at 0.001 second intervals by:
Total force (N) – Subject weight (N)

↓

Impulse (Ns) calculated at 0.001 second intervals by:
(((Net Force Value 1+ Net Force Value 2)/2)*0.001) + Previous Impulse**

↓

Velocity (m/s) calculated at 0.001 second intervals by:
Impulse(Ns)/Mass(kg)

↓

Jump height (m) calculated at 0.001 second intervals by:
(Velocity x 0.001) + Previous Displacement ***

↓

Power (W) calculated at 0.001 second intervals by:
Absolute Force (N) x Velocity (m/s)

Note. * = Subject was standing still during this time; ** = Initial impulse value was zero; *** = Initial displacement was zero. N = Newtons; Ns = Newton seconds; m/s = metres per second; kg = kilograms; m = metres; W = Watts.

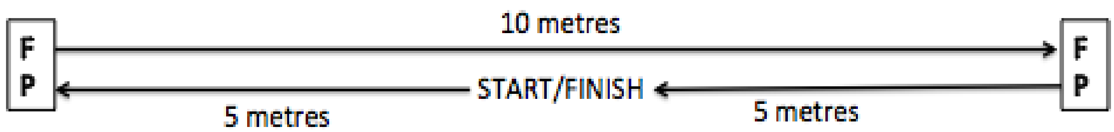
Subjects were instructed to step onto the plates with one foot on each device, standing as still as possible until cue delivery. The appropriate cue was provided, with subjects instructed to perform on the command 'jump' 5 seconds later. Subjects had to perform each jump with a counter swing of the arms and land with two feet on the plates, remaining in position until further instruction. If the landing did not meet this criterion, the jump was repeated. This process was replicated for each jump in all conditions.

Following each CONT VJ trial, subject were asked 'what were you focussing on as you jumped?' This was then categorised as INT, EXT or neutral, and noted for each trial.

In order to build familiarity with jumping technique, it was included within the warm up at submaximal level prior to each session, with a demonstration of technique provided. During warm up delivery, only neutral cues were communicated, minimising impact on subsequent performance. The cues provided to subjects in each VJ trial are shown in Table 2.

Change of Direction Test. The 5-10-5 Pro-Agility test required subjects to start at the half way mark between two points 10 metres apart. The subject stood facing forwards, in a forward lean position, with one hand positioned on the ground and feet either side of the halfway mark. Subjects ran five metres in the direction matching the grounded hand, turning 180 degrees (°), covering a further ten metres before turning 180°, sprinting back towards the start line. The test was repeated four times in each condition, with the subject starting in each direction twice. This is shown in Figure 2.

Figure 2. Pro Agility 5-10-5 Test



Note. The above figure represents a trial starting with movement to the left. FP = Force plate.

Gym floor tiles were removed, allowing force plates to be flush with the performance surface. Coloured tape was placed in the centre of the plate as a guide for the participant as to where foot contact should occur. Each plate gathered GRF during contact time with contact time determined by establishing when GRF exceeded 10N until the force value was below 10N. This is consistent with the work of Spiteri et al. (2015).

Data was further analysed in Excel, where rate of force development (RFD) – peak, RFD contact to half peak, and RFD half peak to peak were calculated in Newtons per second (N/s). Additionally, contact time (s), maximum force (N), time to maximum force (s), and relative net impulse (Ns) were established for each turn. For impulse calculations, each participant's weight was halved, as only one foot was contacting the force plate during CoD. The FreeLap Timing System (Freelap USA, Pleasanton, CA) was used to gather performance time (s) for each test. This system is an electronic timing gate system that makes use of a receiver in the form of a stopwatch that senses the magnetic field released by a set of transmitters. The stopwatch is triggered on each occasion that a subject travels in front of a transmitter.

Prior to performance, subjects were provided with a demonstration of the 5-10-5 Pro-Agility test. During delivery of the warm up, only neutrally focused cues were used to minimise impact on subsequent performance. On turning, subjects were required to make a full foot contact with the force plate. Furthermore, subjects had to make the right and left turns with the corresponding feet. If this criterion was not met, a 'no run' was recorded, with the trial repeated. The appropriate verbal cue was provided, with the subject instructed to perform on the command 'go' 5 seconds later. The cues provided to the subjects in each CoD trial are shown in Table 2. The subject activated the timing system on initial movement of the body, stopping the timer when passing through the finish line. This process was repeated for each condition. Following each CONT CoD trial, subject were asked 'what were you focussing on when you turned?' This was then categorised as INT, EXT or neutral, and noted for each trial.

Table 2.

Cues Provided in Each Trial Condition

Cue	VJ	CoD
INT	'…Focus on straightening your legs explosively…'	'…Focus on straightening your turning leg explosively out of the turn…'
EXT	'…Focus on pushing the ground away…'	'…Focus on pushing the ground away coming out of the turn…'
CONT	'…Jump as high as you can…'	'…Turn as fast as you can…'

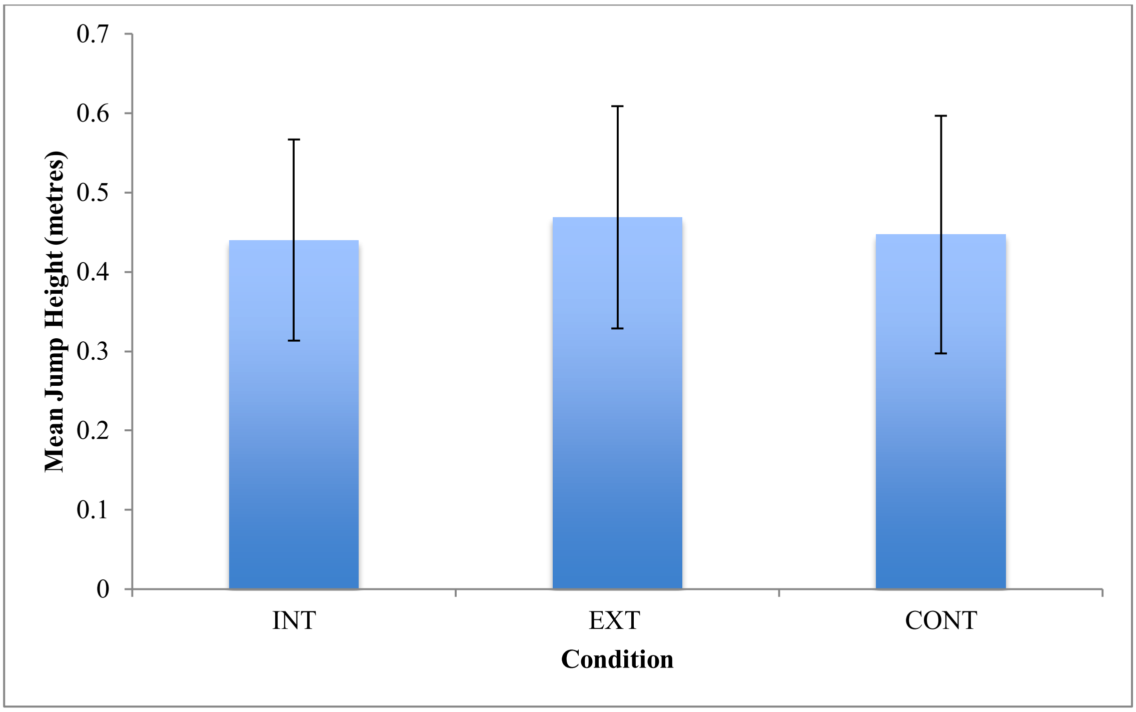
Note. VJ = Vertical Jump; CoD = Change of direction; INT = Internal; EXT = External; CONT = Control.

Statistical Analyses. SPSS Version 21 (IBM Corp, 2012) was utilised to conduct statistical analysis of the data. A one-factor repeated-measures design analysis of variance (ANOVA) was utilised for both tests to firstly determine any interaction between cueing condition and the category of subject. This test was used to establish if differences existed between means of each measure in each condition for both tests. The null hypothesis would be rejected if the *F* value exceeded the critical value at $p<0.05$. Pairwise comparisons revealed which means were significantly different ($p\leq0.05$) from each other, with a Bonferroni adjustment applied to all tests to account for multiple comparisons. A Chi-Square test was used to determine if there was a significant difference ($p<0.05$) in focus preferences between the two groups for each test. For all comparisons, the best performance by height was selected for VJ, and the best performance by time in CoD.

Results

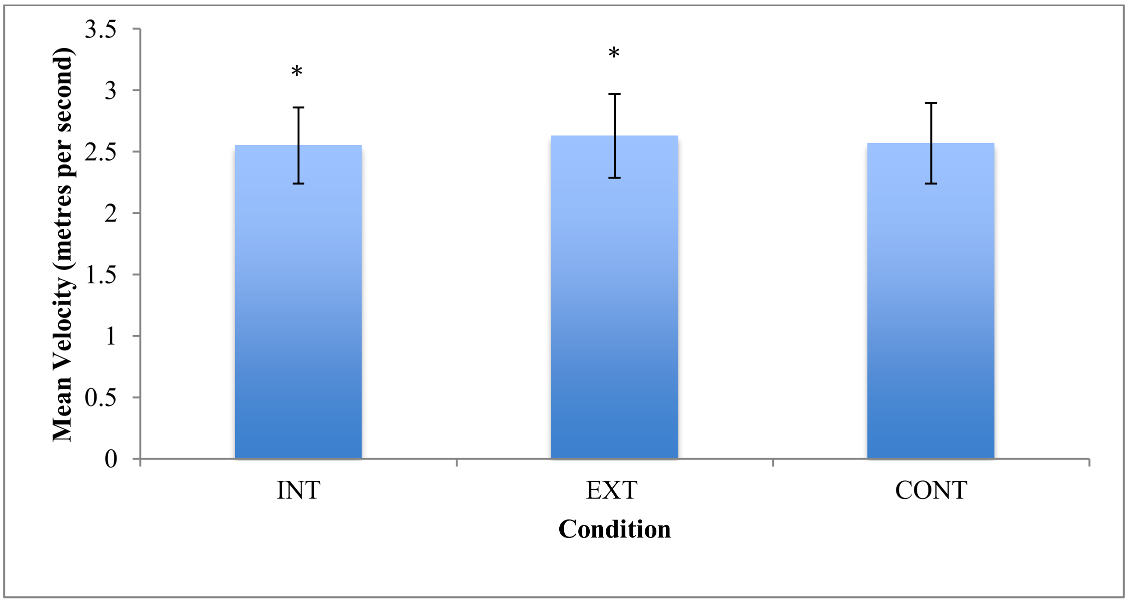
Vertical Jump. No interaction was established between training experience and cueing condition in relation to any performance outcomes ($F(10,3) = 4.40$, $p = 0.13$). Completion of the ANOVA established that with subject grouping removed, significant differences existed for velocity ($F(2,24) = 6.22$, $p < 0.01$), impulse ($F(2,24) = 5.62$, $p = 0.02$), and power ($F(2,24) = 5.84$, $p < 0.01$). There were no significant differences for height ($F(2,24) = 0.89$, $p > 0.05$) or force ($F(1.30,15.7) = 2.15$, $p > 0.05$). Further post-hoc testing revealed a trend for enhanced outcomes in EXT conditions, with EXT cues producing larger peak velocity (see Figure 4), peak power (see Figure 5) and relative net impulse (see Figure 6) when compared with INT conditions. There were no significant differences between CONT and INT or EXT conditions for any performance measure ($p>0.05$). Whilst insignificant, jump height was also greatest in EXT conditions (see Figure 3). Maximum force demonstrated little variance across the three conditions, with mean values of 4006N, 3536N and 3594N for INT, EXT and CONT conditions respectively. Focus preferences in CONT jump trials revealed a trend for INT or neutral for both groups, as shown in Table 3, with no significant difference between preferences of each group ($p=0.19$).

Figure 3. Mean Jump Height by Condition



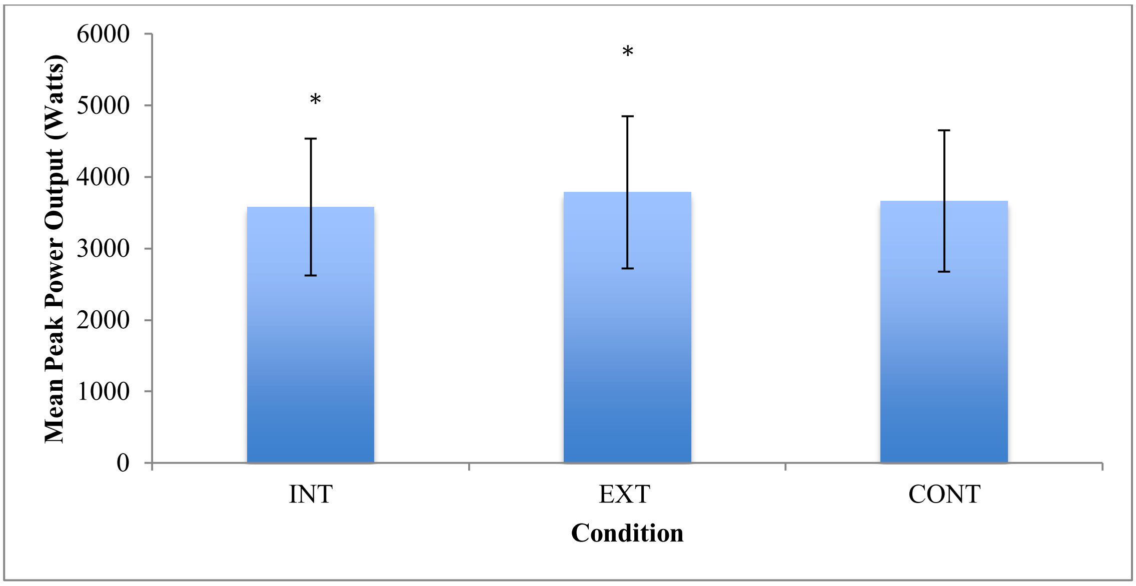
Note. Error bars display ± one standard deviation. There were no statistically significant differences between means. INT = Internal; EXT = External; CONT = Control.

Figure 4. Vertical Jump Mean Peak Velocity by Condition.



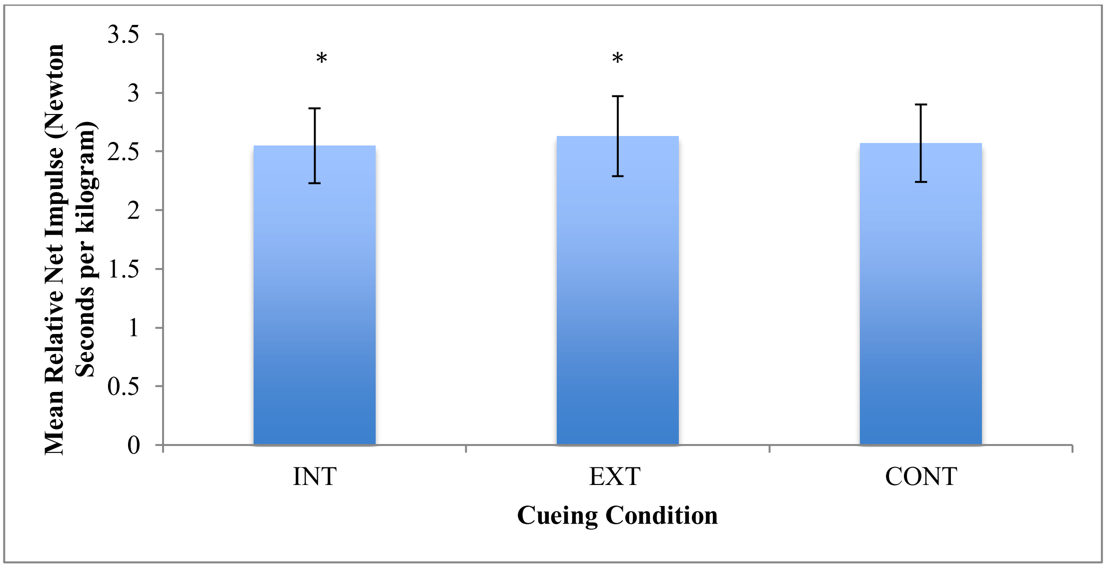
Note. Error bars display ± one standard deviation. * = EXT produced a significantly higher velocity than INT (p=0.04). INT = Internal; EXT = External; CONT = Control.

Figure 5. Vertical Jump Mean Peak Power Output by Condition



Note. Error bars display ± one standard deviation. * = EXT produced a significantly higher power output than INT (p=0.02). INT = Internal; EXT = External; CONT = Control.

Figure 6. Vertical Jump Relative Net Impulse by Condition



Note. Error bars display ± one standard deviation. * = EXT produced significantly higher impulse than INT (p=0.04). INT = Internal; EXT = External; CONT = Control.

Change of Direction. A significant interaction between subject category and cue was established for time to maximum force production on the left leg ($F(2,24) = 4.118$; $p=0.02$). Further analysis of 95% confidence intervals revealed a significant difference between INT trials. The interval range for INT conditions was 0.06 to 0.35, with no zero value present indicating significant difference in the impact of this form of cueing between sedentary and trained subjects. In the sedentary group, the INT condition increased time taken to reach maximum force. This pattern was absent in the trained population, creating a significantly different response. Intervals for EXT (-0.07 to 0.29) and CONT (-0.21 to 0.02) were considered insignificant due to the presence of a zero value within the intervals. There were no other interactions found.

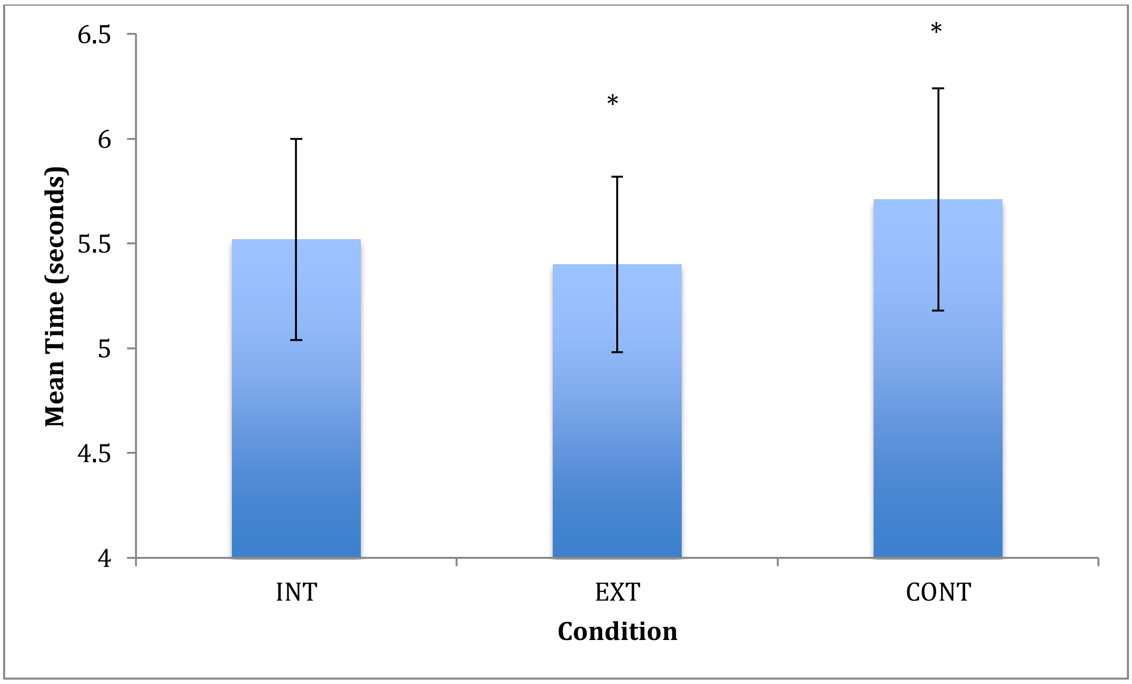
Pairwise comparisons of all performance measures and subjects (grouping removed) revealed no apparent trend in relation to cues provided. EXT cues were favourable in relation to time when compared with CONT conditions. Although insignificant, EXT conditions also produced a quicker time trial than INT conditions (see Figure 7). INT cues produced larger impulse on right turns when compared with CONT conditions (see Figure 8), with EXT cues generating maximal force significantly quicker than INT cues on left turns (see Figure 9).

Contact time demonstrated little variance on both right and left turns in all testing conditions. On the right foot, average contact time was 0.47s, 0.46s and 0.44s for INT, EXT and CONT conditions respectively. On the left foot, contact time was 0.47s, 0.49s and 0.44s for INT, EXT and CONT conditions respectively. None of these differences were statistically significant ($p>0.05$).

Peak force produced on each foot in each testing condition also revealed limited, non-significant differences. On the right foot, mean values were 958N, 923N and 900N for INT, EXT and CONT conditions respectively. On the left foot, mean values were 994N, 980N and 1000N for INT, EXT and CONT conditions respectively. There were no differences in rate of force development measurements on either right or left feet in any of the cueing conditions ($p>0.05$).

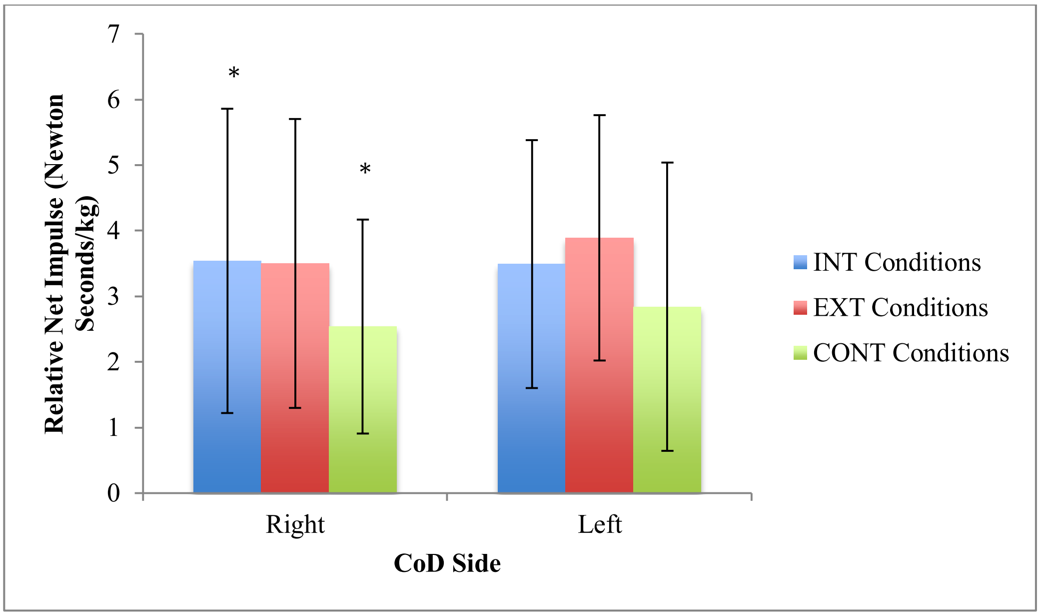
Focus preferences in CONT CoD trials reveal a preference for INT or neutral, as shown in table 3, with no significant difference in preferences between groups ($p=0.34$).

Figure 7. Mean 5-10-5 Pro Agility Trial Times by Condition



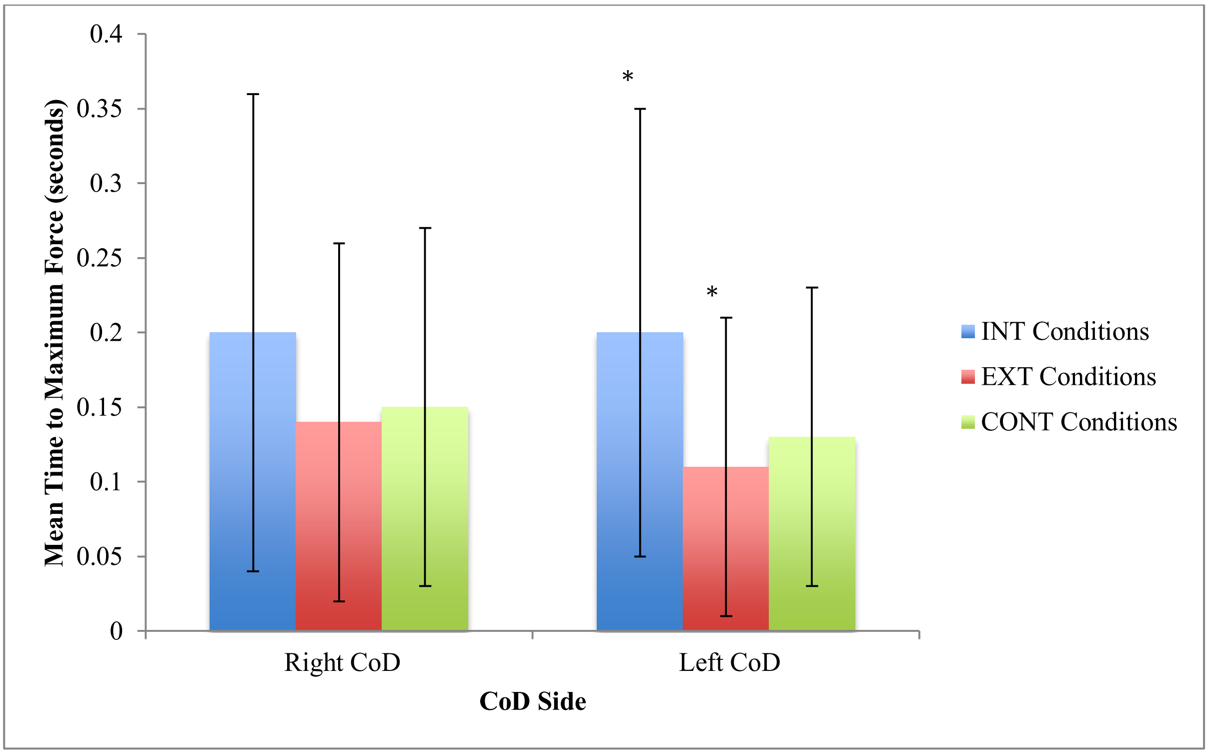
Note. Error bars display ± one standard deviation. * = EXT cues produced a significantly quicker time trial than CONT ($p<0.01$). INT = Internal; EXT = External; CONT = Control.

Figure 8. Mean Relative Net Impulse on Right and Left Change of Direction by Condition



Note. Error bars display ± one standard deviation. * = CONT conditions produced significantly lower impulse values than INT (p=0.01) on right turns. There were no significant differences on left turns. INT = Internal; EXT = External; CONT = Control: kg = kilograms.

Figure 9. Mean Time to Maximum Force on Right and Left Change of Direction by Condition



Note. Error bars display ± one standard deviation. * = Time to maximum force on left turns was significantly faster in EXT when compared with INT (p=0.03). There were no significant differences on right turns. INT = Internal; EXT = External; CONT = Control.

Table 3.

Vertical Jump and Change of Direction Focus Preference in Control Conditions

	Vertical Jump				Change of Direction			
	Sedentary		Trained		Sedentary		Trained	
Focus Preference	Frequency	Percentage	Frequency	Percentage	Frequency	Percentage	Frequency	Percentage
INT	13	72.2	12	50	7	38.9	6	33.3
EXT	1	5.6	0	0	0	0	2	11.1
Neutral	4	22.2	12	50	17	61.1	24	55.6

Note. INT = Internal; EXT = External; CONT = Control.

Discussion

This study indicates that experience of an individual has limited impact upon performance outcomes achieved, following provision of cues encouraging a different focus of attention, in both VJ and CoD. None of the variables measured in jump performance demonstrated an interaction between cueing condition and subject category, with only one of fifteen performance measures demonstrating an interaction in CoD trials. However, this one interaction may provide an interesting insight into the CAH.

The interaction was demonstrated in the variable time to maximum force when turning with the left foot, with INT conditions significantly increasing the time taken in the sedentary group only. The question may be raised as to why this particular measure has been influenced by subject experience, with no others close to significance.

A possible explanation is the difference in cognitive demand associated with turning on the left leg. Each of the sedentary participants identified their strong leg as their right. As such, it would be reasonable to suggest that making a turn on the opposing leg would not be a familiar skill, and the cognitive demand of doing so would be greater than other parts of the test. Whilst seven of the eight trained subjects indicated a preference for their right foot, the skill would be familiar as subjects in this group participated regularly in sports where turning with both legs is a fundamental skill (Sheppard & Young, 2006). It would be fair to suggest that CoD with the weak foot may be the area with potentially greatest difference in performance experience between groups. Whilst an effort was made to ensure participants in the sedentary group had limited physical activity experience, it is unlikely they would be completely unfamiliar with the action of jumping, or CoD using their strong leg.

The CAH states that INT cues negatively impact upon performance automaticity. However, this study finds that INT cues impact negatively in a situation where low automaticity is likely in the sedentary group, with no impact on the trained group where automaticity is likely to be higher. If the CAH were to be true, the opposite result would be expected. The result suggests that INT cues may be more detrimental in instances where performance is more complex and unfamiliar, bringing with it a higher cognitive demand (Fitts and Posner, 1967). The assumption within the CAH of the presence of automaticity in performance if an individual has not previously completed that type of performance seems strange (Muller, 2007), and a substantial limitation of the CAH. In instances such as this, inexperienced performers will already have a large cognitive load when performing the unfamiliar task. The addition of further information in the form of an INT cue creates an environment in which too much information is provided. This agrees with Poolton, Maxwell, Masters, and Raab (2006), who concluded that an INT focus increases cognitive load, and therefore led to decreased performance in putting. This was attributed to the fact that the provision of EXT cues allows the subject to focus only on movement effect information, creating a more implicit learning environment in which EXT cues allow the performer to independently establish the technical components that are central to generating the performance outcome. Whilst an INT cue provides explicit information, placing a focus on proprioceptive feedback, the focus of movement effect is not entirely removed, thus increasing the cognitive demand (Poolton, Maxwell, Masters, & van der Kamp, 2007), and therefore negatively impacting upon performance. Linking this to the model of working memory (Baddeley, 2000), Poolton et al. (2007) suggest explicit information can increase the demands placed on the limited capacity of the working memory, and reduce performance. In initial development of this model, Baddeley and Hitch (1974) provided three key components to the working memory: the central executive, the visuo-spatial scratch pad and the phonological loop. The most important part of this model is the central executive, with the responsibility of deciding what an individual pays attention to. As described above, the use of INT cues can potentially provide the participant with a variety of focus options, as EXT influences are not entirely removed. This creates additional work for the central executive. This is considered to be particularly detrimental to beginner performers, as they will not have experience and information within the long-term memory to draw upon to determine what their attentional focus is best dedicated to.

Interestingly, the theory of overloading working memory suggests that whilst the most obvious impact is in the short term, it will inevitably be detrimental to long term learning, which is of great concern to the coach. Whilst experience and repeat performance will likely reduce the demands placed on the central executive, this theory would suggest that the use of EXT cues throughout coaching can help to limit initial attentional conflict, resulting in enhanced performance development, as the long-term memory is more likely to contain information that provides clarity on how attentional resources are best allocated. However, it is interesting to note that this study suggests that experienced performers, who in theory would have access to this information within their long-term memory, are also affected by increased demands placed on the working memory due to INT cueing.

The conclusion that INT cues interfere with working memory and performance in the short term may be used to support the suggestion that EXT cues are generally favourable in optimising performance with subject grouping removed. EXT conditions produced both higher VJ (0.03m higher than INT and 0.02m higher than CONT conditions), and faster time trials (0.13s faster than INT, and 0.31s faster than CONT). This is consistent with findings across a range of other activities, including golf (Wulf, Lauterbach, & Toole, 1999; Wulf & Su, 2007), standing long jump (Porter et al., 2010) and sprinting (Porter, Wu, Crossley, Knopp, & Campbell, 2015), as well as in vertical jump (Wulf & Dufek, 2009; Wulf, et al., 2010) and CoD (Porter et al., 2010). These results are in line with the CAH. However, the role of automaticity in generating these differences can be questioned based on the lack of interactions discussed previously. The author suggests that CONT conditions would most likely generate a performance that comes naturally to the individual, and with that, a degree of automaticity. The provision of coaching cues would only divert attention away from and interfere with what the subject would normally do, particularly for trained subjects. As such, if the CAH was to be considered accurate, and maintenance of automaticity to be central to performance, it would be expected that CONT conditions would produce the best performance, especially in those with experience. The results of this study indicate that this is not the case.

The opinion that further considerations beyond interference with automaticity is required to fully understand the impact of focus of attention is a common one, and is supported by the findings of this study. As this study examined two groups with assumed differences in automaticity levels, it would be expected that a greater number of interactions between subject category and cue would be seen if automaticity was integral to the CAH. It is however worth considering that no other interactions were established for other performance measures of CoD on the left leg. This coupled with the small sample size within the study may raise some queries as to how important this interaction is, and therefore how certain the conclusions drawn from this can be.

That said, there does appear to be some further support for the consideration of additional motor learning factors through the findings of other studies where cues encouraging different foci of attention were trialled on subjects of varying abilities. Firstly, Perkins-Ceccato, Passmore, and Lee (2003) examined the impact of INT and EXT cues on novice and expert golfers during pitching, concluding that EXT cues suited experienced performers, whilst INT cues suited novice performers. Wulf and Su (2007) also examined golfing performance, finding that EXT cues were beneficial to all performance levels. Given there is a lack of agreement in findings comparing performers of different levels and automaticity, its role within the CAH appears even more debatable. The results indicate the need to consider further factors within the CAH that allow a degree of individualisation of the theory.

An area worth consideration would be the learning preferences of the individual. Learning style theories have well established that verbal instructions have varying impact upon different individuals (Dunn, 2009) depending on their learning preferences, with some learners showing minimal response to this form of delivery. Furthermore, Gonzalez-Haro, Calleja-Gonzalez and Escanero (2010) established that these learning preferences vary with participant level.

It may also be beneficial to conduct research in a more holistic coaching environment. Most commonly, coaching of motor skills will involve a wide range of delivery methods, including verbal instruction, demonstration, the use of visual aids such as video, as well as many other tools

(Massey et al., 2002). Whilst perhaps verbal communication is the most frequently used tool (Gallo & De Marco, 2008), its isolation in this study and others creates an unrealistic coaching environment that may disadvantage the learner who does not respond to these methods. Hayes, Hodges, Scott, Horn, and Williams (2007) identified that a coaching environment that incorporated both verbal instructions and demonstration produced improved movement reproduction when performing previously unfamiliar skills. Consideration of this variety of learning preferences and teaching approaches within the CAH would make it a more robust theory that could be adapted and applied in a more meaningful manner to individual subjects.

Some research also suggests that participant age may impact upon how coaching cues and feedback are received. Sullivan, Kantak, and Burtner (2008) found that children and adults responded differently to coaching cues when learning a new skill. The authors suggest a range of potential causes of this, including the individual's stage of development and previous and current learning experiences.

It is worth highlighting that this is only a sample of some of the potential influencing factors that will differ from one individual to the next. There has been limited work specifically examining how these individual differences impact upon the CAH, and therefore reaching the definitive conclusion that automaticity is the integral component is questionable.

There is a suggestion that the proximity of the cue to the body, as well as the movement effect can impact upon cue effectiveness (Bund, Wiemeyer, & Angert, 2007). It is hypothesised that all cues sit on a continuum of proximity to the body and movement effect, with the use of cues directed further from the body towards the movement outcome considered preferable (Hegele & Erlacher, 2007). In some cases however, an INT cue can provide subjects with a focus closer to the movement outcome than that of an EXT cue, and would therefore be preferable. In the current study, both INT and EXT cues would be considered relatively proximal, and therefore may assist in explaining why there were relatively few significant differences between conditions.

The minimal significant findings and interactions in this study suggest skill components of higher cognitive demand that are less familiar to the inexperienced population would benefit from the use of EXT cues. That said, this would appear to be too broad of generalisation, given the range of sporting skills that are unique in their demands, both physically and psychologically. Given the variations in skills themselves, the broad spectrum of performers that a coach may encounter, and the lack of obvious patterns within this study, suggesting a blanket approach to the use of verbal cues seems unlikely to generate optimal performance universally.

It may be beneficial to consider the complexity of skill being coached and performed, alongside the level of the individual. Ehrlenspiel (2007) suggests individuals will choose to focus attention optimally based on the demands that they perceive. These individual demands would be closely related to the experience of the subject. Furthermore, Hommel (2007) suggests that past performance may influence focus, with success building confidence, permitting more EXT focus, whereas poor performance encourages the performer to examine INT factors. In addition to this, Oudejans, Koedijker, & Beek, (2007) suggest that there are instances where participants with an automated performance and ingrained technique may benefit from INT focus where detailed technical adjustment is required to improve. This may also be true of a rehabilitating athlete who requires muscle activation in a particular area (Marchant, 2007). Evidence demonstrates that INT cues are useful in increasing muscle activity (Lohse et al., 2011; Vance et al., 2004; Wulf et al., 2010). Whilst this increased muscle activity is used within the CAH to explain decreased automaticity, there has been limited explanation provided to indicate what this relationship is (Maurer & Zentgraf, 2007).

The findings of Wulf and Dufek (2009) reported higher displacement in EXT conditions, although this was attributed to higher force production. This is not consistent with the findings of this study, where EXT conditions generated lowest peak force values. Whilst differences were insignificant, peak force values were highest in INT conditions, yet did not result in greater displacement. This may indicate more efficient use of force, with decreased activity in muscles that have minimal impact on performance outcome, produced in EXT conditions, another common benefit cited in the CAH to support EXT cue use (Wulf, 2007). The results of the CoD trial times also support aspects of the CAH, with EXT conditions producing the best performance.

It is interesting to note that cues only significantly impacted on 3 of 14 CoD variables, yet overall time was significantly different between EXT and CONT conditions. This might suggest that EXT coaching cues, even though this was not their focus, may have impacted upon the actions between CoD. This could imply that the content of the cue has a role to play, not just the focus. Kunzell (2007) highlighted that the functionality of the cue was important to consider. For example, whilst a cue may be EXT, it doesn't guarantee that it is of use to performance. A relevant INT cue may be more beneficial than an irrelevant EXT cue. The CAH does not appear to address this, assuming that the coach will consider cue functionality. For example, the EXT cue of 'push the ground away' may have been applied to movement between the CoD points, and in turn generated an improved time. Coaches may benefit from carefully considering the content of the cue, and how this can be applied in overall performance, using verbal instruction as efficiently as possible.

This study, like many others in this field, placed subjects in an artificial environment where they were aware of the scrutiny that their performance was under. This awareness, known as the Hawthorne Effect (McCarney et al., 2007), may have created an environment in which subjects did not perform as they would naturally, and as such disrupt levels of automaticity. For example, on questioning participants on their focus following the control trials in both tests, it was common to receive detailed explanations as to what they had dedicated attention to. It would appear unlikely that those with experience would perform familiar skills such as VJ and CoD with that level of cognition (Wulf, 2007). Marchant (2007) identifies the need to ensure that naturally occurring performance is measured to fully understand the CAH. Whilst difficult to implement, creating an environment in which subjects can perform without such obvious tracking may allow fairer comparisons to be drawn.

The influence of the testing environment may also assist in explaining some of the patterns seen in focus preferences during both VJ and CoD in CONT conditions. It is apparent in the results that an EXT focus was an uncommon preference for both sedentary and trained population groups, yet when provided with the EXT cue, performance improved. The CAH states that it would be expected that an experienced performer would demonstrate EXT focus preferences. However, the unfamiliarity of the nature of performance and detailed analysis discussed above may have altered the focus of participants.

Another reasonable consideration in explaining these preferences is the past exercise instruction model that the subjects had been exposed to. Kunzell, (2007) concluded that it would appear the use of internally focussed cues is a 'norm' within exercise instruction, and as such, may have influenced performers. Supporting this, Marchant (2007) suggests a possible research approach would be to examine the cueing preferences of coaches, determining how this impacts upon performance. If the CAH were to be accurate, it would be expected that coaches of successful performers would demonstrate a preference for EXT cues.

Furthermore, coaching cues provided to subjects were not specific to the individual performances observed. Again, this is not a realistic coaching environment in which cues would be individualised to suit the strengths and weaknesses. This relates closely to the issue of cue functionality raised previously. It may have been beneficial to provide cues with different foci based on the observations of the researcher.

In addition to the unrealistic experimental environment, it should be noted that the small sample size is a substantial limitation of the study, with the researcher unable to recruit the desired number of subjects to give appropriate statistical power to the findings.. Power calculations prior to the completion of the study calculated that a sample size of 32 would be required to achieve power of 0.95 for VJ tests with p=0.05, and a sample of 16 for CoD tests at the same significance level. Failure to achieve this number of participants may firstly contribute to the lack of significant difference between cue conditions in this study, when compared with others in the same field, with a high chance of significant differences going undetected. Furthermore, it questions whether the conclusions drawn can be applied to the wider population.

Finally, it should be recognised that the process of motor learning is normally delivered over a period of months or years. This study, as well as many others in the field, has not measured the impact of coaching cues over a prolonged period. Whilst some impact has been observed across three individual sessions, determining the long-term impact on learning would be of greater benefit to the coach (Bund et al., 2007).

In conclusion, experience and activity levels have limited impact on the effect of cues upon VJ and CoD performance. Whilst the results of the study support the CAH in part, with EXT cues producing optimal performance, the role of automaticity in this should be questioned and investigated further, particularly with larger sample sizes. This study suggests that more attention should be given to the influence of cues on cognitive demand.

The researcher suggests that the CAH would benefit from greater integration of well-established theories of motor learning, as well as additional individual differences that exist between participants. Additionally, treating each performance event as unique in relation to the verbal instruction provided would appear valuable in ensuring the cues used are effective in generating the required response. A generic approach to cueing goes against many theories of motor learning, with this study concluding that a degree of individualisation is essential in the application of any motor development theory.

It appears fair to suggest that the content of a coach's verbal instructions can bear substantial influence on performance, and therefore attention should be paid to specifics of verbal communication, measuring and recording where possible, the impact cues have on individuals.

References

Baddeley, A., & Hitch, G. (1974). Working memory. In G.H. Bower (Ed.), *The psychology of learning and motivation: Advances in research and theory* (pp. 47-89). New York, NY: Academic Press.

Baddeley, A. (2000). The episodic buffer: a new component of working memory? *Trends in Cognitive Sciences, 4*(11), 417-423.

Bund, A., Wiemeyer, J., & Angert, R. (2007) Attentional focus and motor learning: notes on some problems of a research paradigm. *E-Journal Bewegung und Training, 1*, 17-18.

Dunn, J. (2009). Using learning preferences to improve coaching and athletic performance. *Journal of Physical Education, Recreation & Dance, 80*(3), 30-37.

Ehrlenspiel, F. (2007). Constraining action through attentional focussing happens at points in time. *E-Journal Bewegung und Training, 1*, 19-20.

Fitts, P., & Posner, M. (1967). *Human performance.* Belmont, CA: Brooks & Cole.

Ford, K., Myer, G., Smith, R., Byrnes, R., Dopirak, S., & Hewett, T. (2005). Use of an overhead goal alters vertical jump performance and biomechanics. *Journal of Strength and Conditioning Research, 19*(2), 394-399.

Gallo, G., & De Marco, G. (2008). Self-assessment and modification of a division I strength and conditioning coach’s instructional behaviour. *Journal of Strength and Conditioning Research, 22*(4), 1228-1235.

Gonzalez-Haro, C., Calleja-Gonzalez, J., & Escanero, J. (2010). Learning styles favoured by professional, amateur, and recreational athletes in different sports. *Journal of Sports Sciences, 28*(8), 859-966.

Hegele, M., & Erlacher, D. (2007). Focussing along multiple dimensions: spatial, temporal and modal aspects of distality. *E-Journal Bewegung und Training, 1*, 21-22.

Kunzell, S. (2007). Optimal attentional focus in practical sport settings: always external or task specific? *E-Journal Bewegung und Training, 1*, 27-28.

Lohse, K., Sherwood, D., & Healy, A. (2011). Neuromuscular effects of shifting the focus of attention in a simple force production task. *Journal of Motor Behaviour, 43*(2), 173-184.

Makaruk, H., Porter, J., Czaplicki, A., Sadowski, J., & Sacewicz, T. (2012). The role of attentional focus in plyometric training. *Journal of Sports Medicine and Physical Fitness, 52*, 319-327.

Marchant, D. (2007). Staying focussed: additional questions and issues for future attentional focus research. *E-Journal Bewegung und Training, 1*, 29-30.

Massey, D., Maneval, M., Phillips, J., Vincent, J., White, G., & Zoeller, B. (2002). An analysis of teaching and coaching behaviours of elite strength and conditioning coaches. *Journal of Strength and Conditioning Research, 16*(3), 456-460.

Maurer, H., & Zentgraf, K. (2007). On the how and why of the external focus learning advantage. *E-Journal Bewegung und Training, 1*, 31-32.

McCarney, R., Warner, J., Iliffe, S., van Haselen, R., Griffin, M., & Fisher, P. (2007). The Hawthorne effect: a randomised, controlled trial. *BMC Medical Research Methodology, 7*(30), 1-8.

McPherson, S. (2000). Expert-novice differences in planning strategies during collegiate singles tennis competition. *Journal of Sports and Exercise Physiology, 22*, 39-62.

Mullen, R. (2007). Attentional focus and motor learning: some caveats and cautions. *E-Journal Bewegung und Training, 1*, 39-40.

Muller, H. (2007). De-automization in motor learning? Answers and open questions. *E-Journal Bewegung und Training, 1*, 37-38.

O, J., & Hall, C. (2009). A quantitative analysis of athletes' voluntary use of slow motion, real time, and fast motion images. *Journal of Applied Sport Psychology, 21*(1), 15-30.

Oudejans, R., Koedijker, J., & Beek, (2007). An outside view on Wulf's external focus: three recommendations. *E-Journal Bewegung und Training, 1*, 41-42.

Perkins-Ceccato, N., Passmore, S., & Lee, T. (2003). Effects of focus of attention depend on golfers' skill. *Journal of Sports Science, 21*, 593-600.

Poolton, J., Maxwell, J., Masters, R., & Kamp, J. (2007). Moving with an external focus: automatic or simply less demanding? *E-Journal Bewegung und Training, 1*, 43-44.

Poolton, J., Maxwell, J., Masters, R., & Raab, M. (2006). Benefits of an external focus of attention: common coding or conscious processing? *Journal of Sports Sciences, 24*, 89-99.

Porter, J., Nolan, R., Ostrowski, E., & Wulf, G. (2010). Directing attention externally enhances agility performance: a qualitative and quantitative analysis of the efficacy of using verbal instructions to focus attention. *Frontiers in Psychology, 1,* 216.

Porter, J., Ostrowski, E., Nolan, R., Wu, W. (2010). Standing long-jump performance is enhanced when using an external focus of attention. *Journal of Strength and Conditioning Research, 24*(7), 1746-1750.

Porter, J., Wu, W., Crossley, R., Knopp, S., & Campbell, O. (2015). Adopting an external focus of attention improves sprinting performance in low-skilled sprinters. *Journal of Strength and Conditioning Research, 29*(4), 947-953.

Sheppard, J., & Young, W. (2006). Agility literature review: classifications, training and testing. *Journal of Sports Sciences, 24*(9), 919-932.

Spiteri, T., Newton, R., Binetti, M., Hart, N., Sheppard, J., & Nimphius, S. (2015). Mechanical determinants of faster change of direction and agility performance in female basketball athletes. *Journal of Strength and Conditioning Research, 29*(8), 2205-2214.

Sullivan, K., Kantak, S., & Burtner, P. (2008). Motor learning in children: feedback effects on skill acquisition. *Physical Therapy, 88*(6), 720-732.

Tenison, C., & Anderson, J. (2015). Modelling the distinct phases of skill acquisition. *Journal of Experimental Psychology: Learning Memory, and Cognition, Advance online publication.*

Toner, J., & Moran, A. (2007). The influence of attentional focus on motor performance and learning: a brief critique of Gabriele Wulf's article. *E-Journal Bewegung und Training, 1*, 59-50.

Vance, J., Wulf, G., Tollner, T., McNevin, N., & Mercer, J. (2004). EMG activity as a function of the performers focus of attention. *Journal of Motor Behaviour, 36*(4), 450-459.

Weigelt, M., Schack, T., & Kunde, W. (2007). Attentional focus effects highlight the role of mental representations in motor control. *E-Journal Bewegung und Training, 1*, 51-52.

Wrisberg, C. (2007). An applied sport psychology perspective on the relative merits of an external and internal focus of attention. *E-Journal Bewegung und Training, 1*, 53-54.

Wulf, G. (2007). *Attention and motor skill learning.* Leeds: Human Kinetics.

Wulf, G., & Dufek, J. (2009). Increased jump height with an external focus due to enhanced lower extremity joint kinetics. *Journal of Motor Behaviour, 41*(5), 401-409.

Wulf, G., Dufek, J., Lozano, L., & Pettigrew, C. (2010). Increased jump height and reduced EMG activity with an external focus. *Human Movement Science, 29*, 440-448.

Wulf, G., Lauterbach, B., & Toole, T. (1999). The learning advantages of an external focus of attention in golf. *Research Quarterly for Exercise and Sport, 70*(2), 120-126.

Wulf, G., & Su, J. (2007). An external focus of attention enhances golf shot accuracy in beginners and experts. *Research Quarterly for Exercise and Sport, 78*(4), 384-389.

Appendix 1 - Participant Invitation Email

Hi there,

Have you ever wanted to know how quick you are, how much force you can produce or how your performance compares to elite athletes? Now is your chance to find out!

My name is Ewan Birnie. I'm currently studying an MSc in Strength and Conditioning with St Mary's University, Twickenham, London, UK. As part of this study, I'm required to complete a final year research project.

I have chosen to investigate agility and jump performance as my focus of this research. In order to complete this study, I require 30 participants. You will find more specific details about the study in the attachment.

If you would like to participate, or have any further questions, please contact me on the details below. Thank you for your time.

Kind Regards,

Ewan Birnie

135268@live.stmarys.ac.uk

0488046656

Appendix 2 - Participant Information Sheet

Testing the constrained action hypothesis – the impact of internal and external cues on vertical jump and change of direction performance in trained and sedentary populations.

Information Sheet

The Research Project

The study aims to inform 'best practice' guidelines for strength and conditioning coaches in both coaching and testing of their athletes. This will be achieved through the testing of the constrained action hypothesis in vertical jump and change of direction performance. This has not been tested in this manner previously, and with therefore contribute valuable insight as to how this theory can be applied to the instruction and testing of exercise performance.

You are invited to participate in the study - Testing the constrained action hypothesis – the impact of internal and external cues on vertical jump and change of direction performance in trained and sedentary populations. Study participation will require the completion of pre-screening paperwork and attendance at three practical testing sessions, each lasting up to forty minutes. During each testing session, you will be required to perform five vertical jumps, and four 5-10-5 Pro Agility tests.

The research is being conducted by Ewan Birnie, and supervised by Dr. Daniel Cleather of St. Mary's University, Twickenham, UK. The research forms part of the final year of study of the MSc Strength and Conditioning programme.

The results of the study will be analysed and published in a dissertation project, as part of completion of the MSc Strength and Conditioning programme at St. Mary's University, Twickenham, UK. There is no funding source for completion of this project.

Should you require further information, please don't hesitate to contact Ewan Birnie on 135268@live.stmarys.ac.uk or 0488046656. The contact details for the University are St Mary's University, Waldergrave Road, Strawberry Hill, Twickenham, London, TW1 4SX. The phone number is 02082404000.

Your Participation in the Research Project

You have been invited to take part in this research project as it is believed you may meet the inclusion criteria in relation to your physical activity background. Completion of the initial participant screening will confirm this.

You are under no obligation to take part in this study, and can at any time withdraw, informing Ewan via the contact details above.

Your involvement in the study will firstly require the completion of basic paperwork to confirm your suitability for the study, whilst allowing accurate grouping. From here, you will be required to attend three separate testing sessions, each of forty minutes in duration. At the beginning of each session, you will be required to complete a ten minute warm up as instructed. Following this, you will complete five vertical jumps with two minutes rest between performances, followed by four 5-10-5 Pro Agility tests, each separated by three minutes of recovery.

Given the physical nature of participation in physical activity, there are some minor risks of injury, generally of a musculoskeletal nature. This will be managed through an appropriate warm up, detailed instruction and close supervision during all performances.

Your legal rights are not compromised by agreeing to participate in this study, should something go wrong. There are no specific pre-test requirements or pre-cautions required prior to participation in the study.

The data gathered from your performances will be published in the completed dissertation. At all time, participant details will be kept confidential through the use of a participant numbering system, as well as password protected storage of all details.

On completion of the study, you may access your own performance data on request to Ewan. This will be provided to you in a summary table that identifies basic performance measures, as well as biomechanical data on both jump and change of direction.

YOU WILL BE GIVEN A COPY OF THIS FORM TO KEEP TOGETHER WITH A COPY OF YOUR CONSENT FORM

Appendix 3 – Informed Consent and Physical Activity Readiness Questionnaire

St Mary's University Twickenham London

Practical activity consent form

Name of participant:
…………………………………………………………………………………………..

Title of the practical activity:
…………………………………………………………………………………….

Main coordinator and contact details:
………………………………………………………………………….

Participants of the practical activity:

1. I agree to take part in the above practical activity.
2. I have had the practical activity explained to me, and understand what my role will be. All of my questions have been answered to my satisfaction.
3. I understand that I am free to withdraw from the practical activity at any time, for any reason and without prejudice.
4. I have been informed that the confidentiality of the information I provide will be safeguarded.
5. I am free to ask any questions at any time before and during the practical activity.
6. I am aware that I can obtain a copy of this form, and the relevant Confidential Medical History and/or Physical Activity Readiness Questionnaire (PAR-Q) Form.
   Data Protection: I agree to the University College processing personal data which I have supplied. I agree to the processing of such data for any purposes connected with the teaching activity as outlined to me.

Name of participant (print)…………………………Signed………………..….Date………………

Name of witness (print)……………………………..Signed………………..….Date………………

If you wish to withdraw from the practical activity, please advise the practical activity coordinator, and complete the form below.

Title of Project:

I WISH TO WITHDRAW FROM THIS PRACTICAL ACTIVITY

Name: ……………………………………

Signed: …………………………………………Date: …………………………………

SCHOOL OF Sport, health and applied science

CONFIDENTIAL Medical History / Physical Activity Readiness Questionnaire (PAR-Q) FORM

This screening form must be used in conjunction with an agreed Consent Form.

Full Name:		Date of Birth:	
Height (cm):		Weight (kg):	

Have you ever suffered from any of the following medical conditions? If yes please give details:

	Yes	No	Details
Heart Disease or attack	☐	☐	________________
High or low blood pressure	☐	☐	________________
Stroke	☐	☐	________________
Cancer	☐	☐	________________
Diabetes	☐	☐	________________
Asthma	☐	☐	________________
High cholesterol	☐	☐	________________
Epilepsy	☐	☐	________________
Allergies	☐	☐	________________
Other, please give details	☐	☐	________________

Do you suffer from any blood borne diseases? If yes please give details;

Please give details of any **medication** you are currently taking or have taken regularly within the last year:

Please give details of any **musculoskeletal injuries** you have had in the **past 6 months** which have affected your capacity to exercise or caused you to take time off work or seek medical advice:

Other Important Information

During a typical week approximately how many hours would you spend exercising?

If you **smoke** please indicate how many per day:

If you drink **alcohol** please indicate how many units per week

Are you currently taking any **supplements or medication?** Please give details:

Is there any reason not prompted above that would prevent you from participating within the relevant activity?

By signing this document I agree to inform the relevant individual(s) of any change(s) to my circumstances that would prevent me from participating in specific activities.

Signature (Participant): Date:

Signature (Test Coordinator*): Date:

*Test coordinator: The individual responsible for administering the test(s)/session and subsequent data collection

Appendix 4 – Exercise History Questionnaire

St Mary's University Twickenham London

Exercise History Questionnaire

Subject Number: Date of Birth:__/__/__ Gender: M/F

Height (m): Weight (kg): Preferred Foot: R or L

Training Practices

1. How many minutes of physical activity do you particpate in on average in 1 week?

Greater than 150 minutes ☐ Less than 150 minutes ☐

2. Are you currently following a structured training programme?

3. What training activities are included in your current training programme?

4. What is the average number of training days included in your typical training week?

5. Do you currently partake in competitive sport? If yes, please specify the sport and competition level.

6. What training activities have you participated in in the last 3 years?

7. Have you taken part in jump/plyometric training previously? If yes, please provide some specific information (e.g form of training, period of this form of training).

8. Have you taken part in agility training previously? If yes, please provide some specific information (e.g form of training, period of this form of training).

Injury History

1. Are you currently injured? If yes, please specify the injury and length of time for which you have been injured.

2. Has this injury impacted upon your training (i.e. caused you to miss more than 2 weeks of training?)

3. Have you suffered any injury in the past 6 months? If yes, please specify the injury and length of time that this injury was present?

4. Did this injury impact upon your training? (i.e. caused you to miss more than 2 weeks of training?

5. Please list any other injuries from which you have suffered in the past three years that have disrupted your training. Please provide rough dates of injury and rehabilitation time.

Appendix 5 - Subject Recruitment Permission Request
Hi (insert gym/team manager name),

My name is Ewan Birnie. I'm currently studying an MSc in Strength and Conditioning with St Mary's University, Twickenham, London, UK. As part of this study, I'm required to complete a final year research project.

I have chosen to investigate agility and jump performance as my focus of this research. In order to complete this study, I require 30 participants. I write this email to enquire about the possibility of recruiting subjects for this study through (insert gym/team name). This recruitment would require the attached poster to be displayed within your facility. I have also attached more information on the specifics of the study and required participant characteristics.

In return for participating in the study, subjects will be provided with all of their gathered data, which may be used to gauge performance and progress.

If you have any further questions, please don't hesitate to contact me on the details below. Thank you for your help.

Kind Regards,

Ewan Birnie

ewanbirnie@msn.com

0488046656

Appendix 6 – Recruitment Poster

Subject Recruitment Poster

How Agile Are You?

How High Can You Jump?

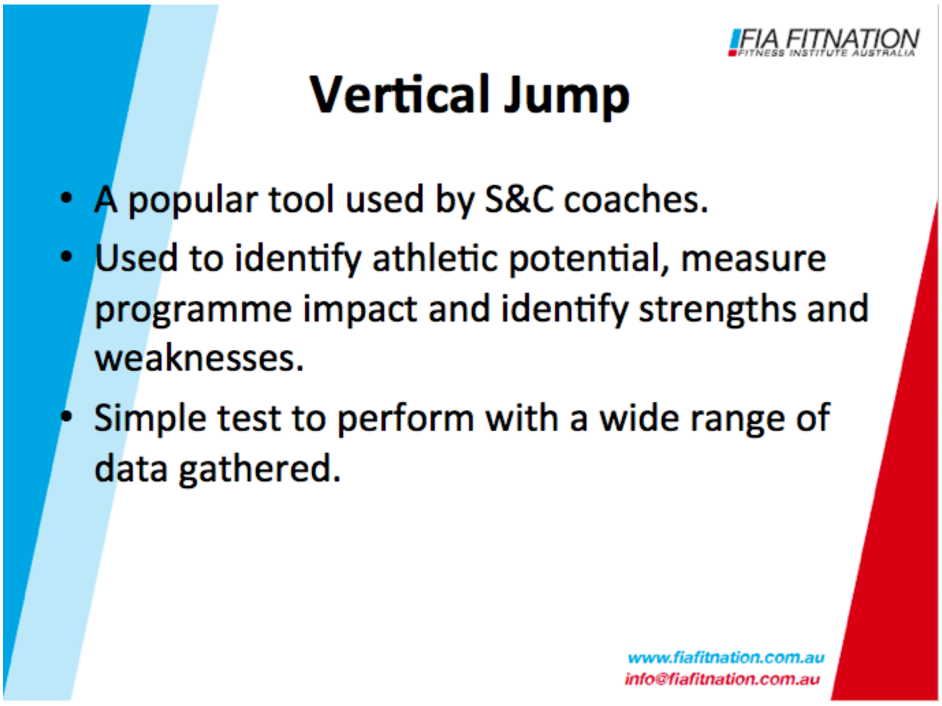
How Do You Compare to Elite Athletes?

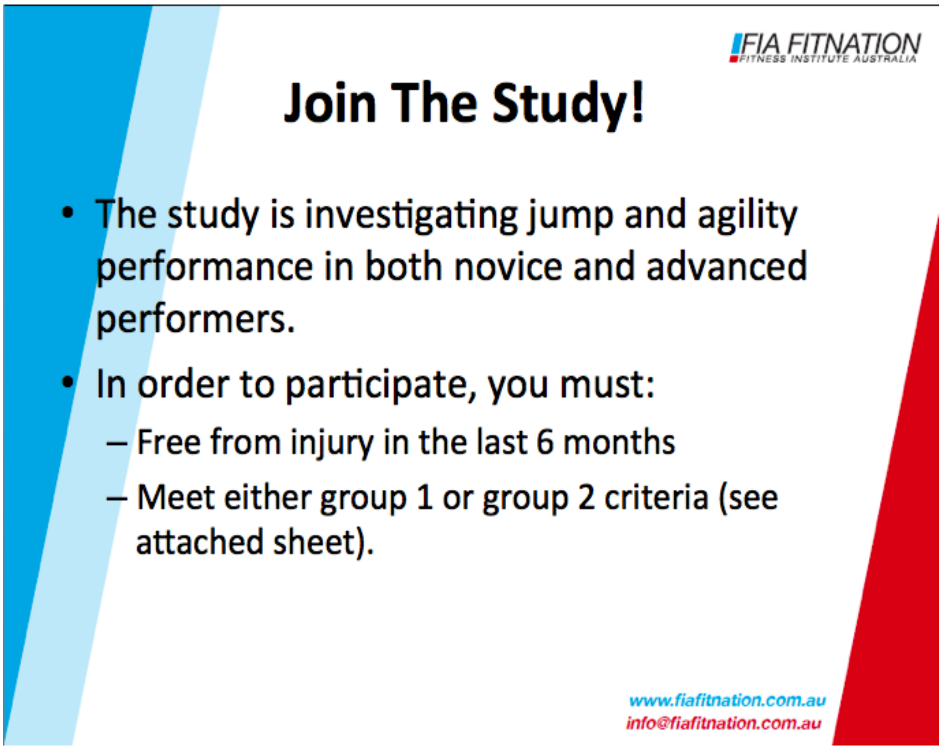
How Much Force Can You Produce?

Have you always wanted to know the answers to these questions? If you have, now is your chance to find out the answers! Join our jump and agility performance study and find out more about your performance.

If you are interested, please contact Ewan on 135268@live.stmarys.ac.uk or 0488046656.

Appendix 7 - Recruitment Presentation


FIA FITNATION
FITNESS INSTITUTE AUSTRALIA
Vertical Jump
• A popular tool used by S&C coaches.
• Used to identify athletic potential, measure programme impact and identify strengths and weaknesses.
• Simple test to perform with a wide range of data gathered.
www.fiafitnation.com.au
info@fiafitnation.com.au


FIA FITNATION
FITNESS INSTITUTE AUSTRALIA
Join The Study!
• The study is investigating jump and agility performance in both novice and advanced performers.
• In order to participate, you must:
– Free from injury in the last 6 months
– Meet either group 1 or group 2 criteria (see attached sheet).
www.fiafitnation.com.au
info@fiafitnation.com.au

FIA FITNATION
FITNESS INSTITUTE AUSTRALIA

What Does it Involve?

- Attend three testing sessions, each of 40 minutes.
- Perform a 10 minute warm up.
- Perform a 5-10-5 agility test on 3 occasions during each testing session.
- Perform 5 vertical jumps in each testing session.

www.fiafitnation.com.au
info@fiafitnation.com.au

FIA FITNATION
FITNESS INSTITUTE AUSTRALIA

What Will I Find Out?

- How agile/fast you are.
- How high you can jump.
- How much force you can produce.
- How your performance compares to elite performers.

www.fiafitnation.com.au
info@fiafitnation.com.au


FIA FITNATION
FITNESS INSTITUTE AUSTRALIA
Want More Information?
• If you would like more information, please take a copy of the information sheet.
• If you would like to participate, or have any questions, please contact me on:
– 135268@live.stmarys.ac.uk
– 0488046656
www.fiafitnation.com.au
info@fiafitnation.com.au

Appendix 8 – Facility Use Permission Letter

FIA FITNATION
FITNESS INSTITUTE AUSTRALIA

To Whom It May Concern:

I can confirm that FIA Fitnation have granted permission to Ewan Birnie to utilise the gym facilities at Level 3, 815 George Street Sydney, in support of the completion of his research as part of the Masters of Strength and Conditioning at St. Mary's University, Twickenham.

Should you have any questions or require any further information, please get in touch via the contact details listed below.

Yours sincerely,

Natalie Daniel
Head of College
FIA Fitnation
Email: Natalie.daniel@fiafitnation.com.au

Sydney (Head Office)
Level 3, 815-825 George Street
Sydney, NSW 2000, Australia
T: 61 2 8204 7800
F: 61 2 9280 4948
Brisbane
362 Water Street, Fortitude Valley
Qld 4006, Australia
T: 61 7 3257 1100
F: 61 7 3257 1900
Melbourne
Suite 3, 197 Bay Street, Brighton
Vic 3186, Australia
T: 61 3 9596 5533
F: 61 3 9596 5236

ABN 57 061 868 264
www.fiafitnation.com.au
info@fiafitnation.com.au

www.facebook.com/FIAFitnation www.twitter.com/FIAFitnation

Appendix 9 – Risk Assessment

SECTION 1: Identify Hazard types - Consider the activity or work area and identify if any of the hazards listed below are significant.

Assessment Reference No.		Activity assessed:	Portable force plate analysis of vertical jump and change of direction performance.	
Assessment date	9th of December 2015			
Persons who may be affected by the activity (i.e. are at risk)	User and Users of activity assessed			
Brief description of activity/procedure	Analysis of vertical jump performance in different coaching conditions. Measurement of displacement, velocity, power, force and impulse through the use of portable force plates.	Description of work to be done:	Please tick (✓) the following which applies:	
			Work to be done in designated areas	✓
			Work to be done under close supervision	✓
			Work to be done in the presence of at least 2 other workers	
			Work to be done within normal hours	✓
			Work not to be left unattended	✓

1	Fall of objects		7	Heating, ventilation and humidity		13	Pressure vessels - autoclave		19	Biological hazards – micro-organisms, human samples or non-lab fieldwork		25	Working at heights	
2	Spillages, slips, Trips & Falls	✓	8	Layout , storage, space, obstructions	✓	14	Noise or Vibration		20	Fire hazards, flammable materials and explosion		26	Occupational stress	
3	Manual handling operations including repetitive movements	✓	9	Electrical Equipment	✓	15	Sharps – syringes, blades		21	Handling food		27	Violence to staff / verbal assault	
4	Display screen equipment	✓	10	Physical hazards – electrical, temperature		16	Ergometers – rower, treadmill, bikes		22	Vehicles and driving		28	Lone working / work out of hours	
5	Work in public areas		11	Contractors		17	Ionising and non-ionising radiation		23	Physical Activity	✓	29	Confined spaces	

6	Lighting levels		12	Mechanical (machinery) and use of portable tools / equipment	✓	18	Chemical hazards – toxic, corrosive, flammables		24	Outdoor work		30	Other(s) - specify	

SECTION 2: Risk Controls - For each hazard identified in Section 1, complete Section 2. Please refer to the Risk Assessment Guidance notes on simmsCAPital folder for Risk Matrix. **Please note that <u>L refers to Likelihood</u>; <u>S refers to Severity</u> and RS refers to Risk Score (L times S equals RS)**

Hazard No.	Outcome due to Hazard description (Substance / equipment / procedure)	Initial risk Level (tick one) Refer to the risk matrix			Controls needed to eliminate or adequately reduce risks	Remaining Risk Level (tick one)		
		High (13-25)	Med (5-12)	Low (0-4)		High (13-25)	Med (5-12)	Low (0-4)
2	Spillages, slips, trips & falls – wires.		✓		Ensure that all wires from force plates and laptop are taped securely to the floor. Ensure adequate space around the force plates. Pre-test check of facility.			✓
3	Manual handling operations including repetitive movements – force plates, laptop.		✓		Ensure user is familiar with setup protocol. Refer to manual handling guide. In the instance of heavy lifting, assistance will be sought from other personnel, and appropriate equipment used.			✓
4	Display screen equipment – laptop.			✓	Equipment is checked prior to each test performance. Ensure user familiarity with the equipment. Position equipment appropriately to minimise distraction for test participants.			✓

8	Layout, storage, space, obstructions – all equipment, gym floor.		✓		Pre-test checks of facility to ensure all obstructions are removed and there is adequate space for equipment setup. Equipment to be stored is assigned storage areas at non-testing times. Continuous review of space through test performance. The testing space will be booked out removing the risk of external gym users.			✓
9	Electrical equipment – force plates, laptop.		✓		Users should be familiar with equipment setup. All wires and equipment should be checked prior to each use. Ensure no fluid consumption next to equipment. Switch off equipment when not in use. Ensure equipment is PAT tested as required. Do not connect numerous extension leads together.			✓
12	Mechanical (machinery) and use of portable tools/equipment – force plates, laptop.		✓		User should be familiar with and trained in the use of the equipment.			✓

23	Physical activity – warm up, vertical jump, change of direction cool down.		✓		All equipment and testing environment to be checked prior to test performance. Ensure participant is familiar with all aspects of the protocol and provided with the opportunity to ask questions. Ensure all test participants have signed an informed consent form and completed a Physical Activity Readiness Questionnaire (PAR-Q) Test subjects to be supervised at all times. Ensure the provision of clear instructions to all test participants. Test participants to be provided with instructions on how to perform the vertical jump and agility test safely, with particular reference to landing and turning. Demonstration of correct technique provided. Researcher to be suitably qualified to supervise and observe performance, ceasing activity should it be deemed unsafe to continue. Close monitoring of participant tolerance to exercise testing, with testing to be ceased if continuation deemed unsafe. Presence of a fully qualified first aider during all testing, with additional staff available to assist in the case of injury.			✓

SECTION 3: Action Plan in the event of an emergency - For each hazard identified in Section 2, complete Section 3.
- Please refer to the Risk Assessment Guidance.

Hazard Number	Hazard Description – Substance / equipment / procedure	Action required (describe)
2	Spillages, slips, trips & falls.	Apply relevant First Aid and seek Medical Assistance where appropriate
3	Manual handling operations including repetitive movements.	Apply relevant First Aid and seek Medical Assistance where appropriate
4	Display screen equipment.	Apply relevant First Aid and seek Medical Assistance where appropriate
8	Layout, storage, space, obstructions	Apply relevant First Aid and seek Medical Assistance where appropriate
9	Electrical equipment	Apply relevant First Aid and seek Medical Assistance where appropriate
12	Mechanical (machinery) and use of portable tools/equipment.	Apply relevant First Aid and seek Medical Assistance where appropriate
23	Physical activity	Apply relevant First Aid and seek Medical Assistance where appropriate

SECTION 4: Arrangement for supervision and/or monitoring effectiveness of control
- For each hazard identified in Sections 2/3, complete Section 4.
- Please refer to the Risk Assessment Guidance notes.

Hazard No.	Hazard Description – Substance/equipment/procedure	Comments
2	Spillages, slips, trips & falls.	Monitoring achieved through pre and post checks, continual supervision by test coordinator and/or separately recruited individual where further supervision is required.
3	Manual handling operations including repetitive movements.	Monitoring achieved through pre and post checks, continual supervision by test coordinator and/or separately recruited individual where further supervision is required.
4	Display screen equipment.	Monitoring achieved through pre and post checks, continual supervision by test coordinator and/or separately recruited individual where further supervision is required.
8	Layout, storage, space, obstructions	Monitoring achieved through pre and post checks, continual supervision by test coordinator and/or separately recruited individual where further supervision is required.
9	Electrical equipment	Monitoring achieved through pre and post checks, continual supervision by test coordinator and/or separately recruited individual where further supervision is required.
12	Mechanical (machinery) and use of portable tools/equipment.	Monitoring achieved through pre and post checks, continual supervision by test coordinator and/or separately recruited individual where further supervision is required.
23	Physical activity	Monitoring achieved through pre and post checks, continual supervision by test coordinator and/or separately recruited individual where further supervision is required.

SECTION 5: Further comments – If a more complex assessment is required, continue below:

IMPORTANT CONTACT DETAILS (including where activities are undertaken off campus): St Mary's University College Security – 0208 240 4335 (advise in the event of calling the emergency services) FIA Fitnation Gym Facilities – 0282047807 FIA Fitnation Office - 0292804948 GUIDELINES FOR REFFERAL (as a hard copy attachment, listed web link or other source): (Examples of supporting information could be a Material Safety Data Sheet (MSDS) or a Qualification/Accreditation guideline).

SECTION 6: Period of cover – If a more complex assessment is required, continue below:

By signing this risk assessment I confirm that I have read and understood all of the risks associated with the activity specified on sheet 1, and that I will follow all of the specified controls to reduce the risks identified with the activity.

PERIOD OF COVER FOR TASK/EVENT		PRINT NAME OF TASK/EVENT LEADER	SIGNATURE	DATE SIGNED	HAZARDS IDENTIFIED (mark with a tick or a cross)
FROM	TO				
4/1/16	16/3/16	Ewan Birnie		16/12/15	X

Appendix 10 – Dissertation Completion Timeline

The table below outlines the proposed completion timeline for each of the key tasks within the dissertation. The completion process is over 46 weeks (3rd August 2015 to 29th of June 2016). Each shaded box corresponds with a time at which the associated task will be completed. This table represents a plan that may be changed, depending on the circumstances that present during each stage of the process.

Week Number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46
Background Reading	■	■	■	■																																										
Proposal Writing		■	■	■	■	■																																								
Proposal Review							■																																							
Proposal Hand In							■																																							
Supervisor Assigned								■																																						
Meeting with Supervisor								■		■		■			■			■								■		■				■		■			■			■			■		■	
Proposal Changes								■	■	■																																				
Completion of Ethics										■	■																																			
Excel & SPSS												■																																		
Data Collection													■	■	■	■	■				■	■	■	■	■																					
Intro & Methods																					■	■	■	■	■																					
Data Analysis																										■	■	■																		
Results																													■	■	■															
Discusssion & Conclusion																																■	■	■	■	■										
Review																																					■	■	■							
Initial Submission																																							■							
Poster Prep																																							■	■	■			■	■	
Feedback Received																																									■					
Make Changes																																										■	■			
Poster Presentation																																														■
Viva																																														■

Appendix 11 – Vertical Jump Raw Data

	Category	Gender	Mass	HeightINT	HeightEXT	HeightCONT	VelINT	VelEXT	VelCONT	PowerINT	PowerEXT	PowerCONT	ImpulseI...	ImpulseEXT	ImpulseCONT	ForceINT	ForceEXT	ForceCONT
1	2	1	80.23	.699	.762	.787	3.044	3.323	3.108	5086.833	5517.961	5015.471	3.048	3.278	3.108	4274.800	4573.350	2855.770
2	1	1	86.09	.439	.413	.576	2.677	2.632	2.734	4142.773	4074.327	4238.328	2.678	2.633	2.729	6408.810	6471.710	5712.570
3	2	1	77.73	.548	.550	.517	2.749	2.780	2.789	4221.881	4290.300	4411.396	2.733	2.766	2.776	5333.280	4649.490	4936.360
4	2	1	83.24	.597	.528	.501	2.556	2.684	2.625	3379.678	4046.544	3642.799	2.556	2.685	2.622	3841.030	3564.540	3407.340
5	2	2	65.12	.429	.618	.448	2.540	2.667	2.582	2909.331	3299.883	3085.135	2.542	2.664	2.581	2826.500	267.040	3100.690
6	2	1	67.93	.501	.442	.452	2.783	2.764	2.765	3453.057	3449.713	3537.497	2.786	2.762	2.763	4248.240	4145.880	4330.160
7	1	2	58.34	.386	.423	.387	2.378	2.499	2.401	2829.307	2861.131	2831.425	2.380	2.496	2.405	2897.570	3642.060	2994.540
8	1	2	86.89	.265	.176	.125	2.100	2.088	1.973	3029.940	2977.879	2769.896	2.087	2.068	1.973	3200.130	4124.820	4123.410
9	2	1	76.27	.498	.602	.532	2.852	2.966	2.851	3968.882	4324.177	4376.177	2.853	2.960	2.851	4510.390	4818.390	3413.690
10	1	2	64.26	.432	.443	.445	2.503	2.491	2.507	2429.292	2468.899	2507.887	2.501	2.488	2.504	1760.220	2612.460	2192.620
11	2	1	85.99	.505	.500	.517	2.888	2.892	2.882	4913.389	5162.955	5105.907	2.884	2.891	2.879	2918.200	2015.270	2246.410
12	1	1	91.31	.305	.371	.387	2.306	2.522	2.373	4024.407	4506.624	4116.820	2.301	2.518	2.367	3243.200	3253.190	4407.640
13	1	2	61.25	.264	.366	.283	1.880	1.912	1.942	1637.441	1613.107	1687.591	1.879	1.912	1.941	1819.030	1563.080	3047.070
14	2	1	90.28	.319	.381	.304	2.474	2.636	2.428	4092.549	4391.537	3942.388	2.473	2.635	2.428	4098.090	4254.990	4460.210

Appendix 12 – Change of Direction Raw Data (Internal Cueing Conditions)

	Category	Gender	Mass	TimeINT	RFDPeakRINT	RFDtoHPeak RINT	RFDHPeaktoPeak RINT	NetImpulse RINT	Contact RINT	MaxForce RINT	TimeMaxForce RINT	RFDPeak LINT	RFDtoHP LINT	RFDHPeaktoPeak LINT	NetImpulse LINT	ContactL INT	MaxForce LINT	TimeMaxForce LINT
1	2	1	80.320	5.280	8444.380	9682.336	6810.511	4.543	.435	1156.88	.137	3109....	4925.26	1093.53	3.264	.466	970.050	.312
2	1	1	85.965	5.790	3563.456	6470.738	563.423	3.356	.425	1061.91	.298	2579....	3801.10	1269.40	3.351	.514	1031.84	.400
3	2	1	77.363	4.870	24828.89	13227.778	35733.889	.932	.330	893.840	.036	52037...	61857.1	40454.3	1.344	.299	728.520	.014
4	2	1	83.291	5.090	19081.63	22458.776	15064.898	3.134	.480	935.000	.049	3586....	5834.38	647.875	.539	.444	573.760	.160
5	2	2	65.167	5.120	2569.766	4732.536	290.087	5.001	.488	881.430	.343	16236...	10341.9	21679.1	2.336	.360	1039.16	.064
6	2	1	67.845	4.930	2670.247	3495.769	1787.198	5.205	.487	971.970	.364	13843...	23389.9	3743.06	6.583	.617	1176.72	.085
7	1	2	58.336	5.790	37132.81	31236.250	42416.875	6.384	.576	1188.25	.032	1428....	1926.93	872.024	5.563	.644	712.700	.499
8	1	2	86.887	5.940	1521.523	2313.775	530.596	-2.179	.387	229.750	.151	4716....	7485.46	1612.73	2.307	.408	890.470	.187
9	2	1	76.274	5.280	1542.840	2720.605	285.412	6.630	.739	917.990	.595	86235...	95178.3	76393.9	7.164	.596	1983.42	.023
10	1	2	64.263	5.870	19929.56	16291.556	22904.000	5.163	.603	896.830	.045	21830...	20137.9	22974.9	3.794	.443	851.390	.039
11	2	1	85.985	5.650	4964.112	5717.103	4057.477	1.876	.438	1062.32	.214	6958....	9232.04	4557.85	3.372	.455	1294.31	.186
12	1	1	91.314	6.430	3691.505	6408.294	825.084	4.033	.566	1103.76	.299	3398....	6327.42	410.629	4.273	.525	1080.63	.318
13	1	2	61.220	6.100	8248.660	12153.402	3464.742	2.541	.330	800.120	.097	2187....	3984.55	259.422	2.296	.382	605.840	.277
14	2	1	90.283	5.150	7662.500	11450.465	3573.140	2.975	.344	1317.95	.172	3280....	5697.05	765.906	2.657	.471	977.540	.298

Change of Direction Raw Data (External Cueing Conditions)

TimeEXT	RFDPeakR EXT	RFDtoHPeak REXT	RFDHPeaktoPeakR EXT	NetImpulseR EXT	Contact REXT	MaxForce REXT	TimeMaxForce REXT	RFDPeak LEXT	RFDtoHP LEXT	RFDHPeaktoPeak LEXT	NetImpulse LEXT	ContactL EXT	MexForce LEXT	TimeMaxForceL EXT
5.070	4382.439	7926.179	692.602	5.212	.480	1078.08	.246	3407....	5856.61	817.469	4.820	.478	1103.88	.324
5.230	13600.93	21373.72	5489.070	1.413	.242	1169.68	.086	33103...	47682.1	17505.8	4.499	.400	1257.93	.038
5.220	22115.93	30842.94	10174.815	1.352	.390	597.130	.027	9593....	12934.0	6032.90	2.806	.399	892.150	.093
5.070	2838.148	5344.242	211.987	2.232	.424	842.930	.297	21454...	22561.9	16565.0	.962	.469	686.530	.032
5.230	5368.636	8639.318	1894.659	4.934	.476	944.880	.176	19130...	24441.4	12869.3	3.044	.581	1109.57	.058
4.810	2177.026	3105.132	1125.803	5.672	.549	907.820	.417	8565....	11337.6	5383.73	4.240	.482	101.670	.118
5.630	18393.20	13560.00	22704.000	6.070	.555	916.660	.050	18809...	16094.7	20928.2	5.211	.567	921.650	.049
5.940	3572.069	6465.747	412.184	-1.386	.293	310.770	.087	7105....	12951.5	724.839	1.486	.339	881.080	.124
5.220	36232.96	33044.44	38072.593	5.236	.589	978.290	.027	58655...	40265.9	76187.4	6.551	.650	1583.71	.027
5.710	16116.03	13801.38	17865.172	5.337	.635	934.730	.058	32193...	38595.4	23209.1	7.538	.787	1126.77	.035
5.450	3770.000	5504.387	1868.922	1.345	.358	1014.13	.269	4695....	8271.72	1040.37	3.877	.469	1258.45	.268
6.030	24169.42	14748.08	33128.462	3.911	.479	1256.81	.052	5412....	9266.98	1422.08	3.296	.369	1147.47	.212
6.080	8937.625	8727.250	8917.000	4.560	.571	715.010	.080	17888...	15404.3	18547.1	4.564	.490	751.310	.042
4.850	6765.775	12081.50	1237.968	3.075	.369	1265.20	.187	3945....	7190.22	612.687	1.628	.387	895.730	.227

Change of Direction Raw Data (Control Conditions)

TimeCONT	RFDPeak CONTR	RFDtoHP CONTR	RFDHpeaktoPeak CONTR	NetImpulse CONTR	Contact CONTR	MaxForce CONTR	TimeMaxForce CONTR	RFDPeak CONTL	RFDtoHP CONTL	RFDHPeaktoPeak CONTL	NetImpulse CONTL	Contact CONTL	MaxForce CONTL	TimeMaxForce CONTL
5.100	7337....	8387.66	5986.95	3.552	.427	1034.55	.141	4659....	6619.79	2516.06	1.745	.356	922.630	.198
5.970	35112...	42981.1	26486.1	3.186	.398	1264.05	.036	57820...	61620.0	52606.9	5.465	.471	1676.78	.029
5.280	25615...	31417.1	18640.0	.318	.383	537.920	.021	11848...	109035	108573	2.055	.315	947.840	.008
5.380	3150....	5635.99	402.561	3.069	.482	910.410	.289	15340...	11299.2	18428.2	1.439	.662	751.690	.049
5.690	5239....	8285.93	2054.88	3.135	.377	901.250	.172	7926....	3938.23	11684.8	.990	.461	627.810	.079
4.840	3432....	5910.28	755.304	3.166	.403	847.740	.247	4439....	7816.26	865.911	3.382	.402	901.150	.203
6.470	1213....	1904.58	170.444	3.198	.568	546.230	.450	2031....	3666.19	283.220	1.131	.354	479.360	.236
6.280	5157....	4038.79	5950.00	-1.248	.289	341.030	.066	20899...	13777.3	25413.3	1.716	.367	940.490	.045
5.570	43667...	60106.3	24447.5	5.666	.838	1397.35	.032	98990...	108369	87997.0	8.944	.757	1979.80	.020
5.850	20250...	12847.5	25223.0	3.101	.453	810.020	.040	2470....	3625.05	1070.16	4.373	.485	793.140	.321
5.750	4146....	6427.52	1742.76	1.357	.396	870.720	.210	7998....	9695.54	5937.71	2.919	.380	1327.82	.166
6.250	5142....	9684.30	401.402	2.862	.459	1100.41	.214	4191....	7400.00	895.630	2.495	.468	997.670	.238
6.460	16787...	14826.4	16926.0	1.793	.276	889.720	.053	21411...	26522.6	15672.8	2.261	.327	835.030	.039
5.100	6023....	9676.13	2218.74	2.445	.353	1150.45	.191	3752....	5756.79	1611.28	.787	.370	818.070	.218

Appendix 13 SPSS – Vertical Jump Output

Descriptive Statistics

	Category	Mean	Std. Deviation	N
HeightINT	Sedentary	.34850	.080714	6
	Trained	.51200	.112119	8
	Total	.44193	.127768	14
HeightEXT	Sedentary	.36533	.097478	6
	Trained	.54788	.116769	8
	Total	.46964	.140658	14
HeightCONT	Sedentary	.36717	.152437	6
	Trained	.50725	.134682	8
	Total	.44721	.154532	14
VelINT	Sedentary	2.30733	.284793	6
	Trained	2.73575	.197579	8
	Total	2.55214	.317209	14
VelEXT	Sedentary	2.35733	.286829	6
	Trained	2.83900	.225869	8
	Total	2.63257	.346844	14
VelCONT	Sedentary	2.32167	.309519	6
	Trained	2.75375	.208722	8
	Total	2.56857	.330974	14
PowerINT	Sedentary	3015.52667	955.635968	6
	Trained	4003.20000	750.968255	8
	Total	3579.91143	955.085193	14
PowerEXT	Sedentary	3083.66117	1059.000816	6
	Trained	4310.38375	758.172364	8
	Total	3784.64550	1066.650792	14
PowerCONT	Sedentary	3025.32450	982.125566	6
	Trained	4139.59625	716.227142	8
	Total	3662.05121	987.251114	14
ImpulseINT	Sedentary	2.30429	.287023	6
	Trained	2.73428	.198021	8
	Total	2.55000	.318690	14
ImpulseEXT	Sedentary	2.35258	.290099	6
	Trained	2.83013	.212854	8
	Total	2.62547	.341922	14
ImpulseCONT	Sedentary	2.31979	.308301	6
	Trained	2.75111	.208417	8
	Total	2.56626	.330170	14
ForceINT	Sedentary	3221.49333	1695.114426	6
	Trained	4006.31625	824.381941	8
	Total	3669.96357	1278.103222	14
ForceEXT	Sedentary	3611.22000	1659.380823	6
	Trained	3536.11875	1596.823319	8

	Total	3568.30500	1559.979645	14
	Sedentary	3746.30833	1258.076905	6
ForceCONT	Trained	3593.82875	907.577009	8
	Total	3659.17714	1028.792199	14

Vertical Jump Repeated Measures ANOVA - Univariate Tests

Source	Measure		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	
Condition	Height	Sphericity Assumed	.005	2	.003	.886	.426	.069	1.771
		Greenhouse-Geisser	.005	1.984	.003	.886	.425	.069	1.757
		Huynh-Feldt	.005	2.000	.003	.886	.426	.069	1.771
		Lower-bound	.005	1.000	.005	.886	.365	.069	.886
	Velocity	Sphericity Assumed	.045	2	.022	6.223	.007	.342	12.447
		Greenhouse-Geisser	.045	1.534	.029	6.223	.013	.342	9.546
		Huynh-Feldt	.045	1.861	.024	6.223	.008	.342	11.580
		Lower-bound	.045	1.000	.045	6.223	.028	.342	6.223
	Power	Sphericity Assumed	245410.723	2	122705.361	5.842	.009	.327	11.683
		Greenhouse-Geisser	245410.723	1.721	142608.180	5.842	.012	.327	10.053
		Huynh-Feldt	245410.723	2.000	122705.361	5.842	.009	.327	11.683
		Lower-bound	245410.723	1.000	245410.723	5.842	.032	.327	5.842
	Impulse	Sphericity Assumed	.039	2	.020	6.304	.006	.344	12.607
		Greenhouse-Geisser	.039	1.544	.025	6.304	.012	.344	9.733
		Huynh-Feldt	.039	1.876	.021	6.304	.008	.344	11.827
		Lower-bound	.039	1.000	.039	6.304	.027	.344	6.304
	Force	Sphericity Assumed	64301.965	2	32150.983	.075	.928	.006	.149
		Greenhouse-Geisser	64301.965	1.309	49114.296	.075	.851	.006	.098
		Huynh-Feldt	64301.965	1.527	42098.568	.075	.883	.006	.114
		Lower-bound	64301.965	1.000	64301.965	.075	.789	.006	.075
Condition * Category	Height	Sphericity Assumed	.003	2	.002	.537	.591	.043	1.074
		Greenhouse-Geisser	.003	1.984	.002	.537	.590	.043	1.065
		Huynh-Feldt	.003	2.000	.002	.537	.591	.043	1.074
		Lower-bound	.003	1.000	.003	.537	.478	.043	.537

	Velocity	Sphericity Assumed	.006	2	.003	.844	.442	.066	1.687
		Greenhouse-Geisser	.006	1.534	.004	.844	.418	.066	1.294
		Huynh-Feldt	.006	1.861	.003	.844	.436	.066	1.570
		Lower-bound	.006	1.000	.006	.844	.376	.066	.844
	Power	Sphericity Assumed	98076.449	2	49038.225	2.335	.118	.163	4.669
		Greenhouse-Geisser	98076.449	1.721	56992.228	2.335	.128	.163	4.017
		Huynh-Feldt	98076.449	2.000	49038.225	2.335	.118	.163	4.669
		Lower-bound	98076.449	1.000	98076.449	2.335	.152	.163	2.335
	Impulse	Sphericity Assumed	.005	2	.003	.808	.457	.063	1.616
		Greenhouse-Geisser	.005	1.544	.003	.808	.431	.063	1.248
		Huynh-Feldt	.005	1.876	.003	.808	.451	.063	1.516
		Lower-bound	.005	1.000	.005	.808	.386	.063	.808
	Force	Sphericity Assumed	1855991.949	2	927995.975	2.154	.138	.152	4.307
		Greenhouse-Geisser	1855991.949	1.309	1417619.774	2.154	.159	.152	2.820
		Huynh-Feldt	1855991.949	1.527	1215119.987	2.154	.153	.152	3.289
		Lower-bound	1855991.949	1.000	1855991.949	2.154	.168	.152	2.154
Error(Condition)	Height	Sphericity Assumed	.069	24	.003				
		Greenhouse-Geisser	.069	23.810	.003				
		Huynh-Feldt	.069	24.000	.003				
		Lower-bound	.069	12.000	.006				
	Velocity	Sphericity Assumed	.086	24	.004				
		Greenhouse-Geisser	.086	18.406	.005				
		Huynh-Feldt	.086	22.328	.004				
		Lower-bound	.086	12.000	.007				
	Power	Sphericity Assumed	504134.357	24	21005.598				
		Greenhouse-Geisser	504134.357	20.650	24412.708				
		Huynh-Feldt	504134.357	24.000	21005.598				
		Lower-bound	504134.357	12.000	42011.196				

Impulse	Sphericity Assumed	.075	24	.003				
	Greenhouse-Geisser	.075	18.529	.004				
	Huynh-Feldt	.075	22.515	.003				
	Lower-bound	.075	12.000	.006				
Force	Sphericity Assumed	10341539.009	24	430897.459				
	Greenhouse-Geisser	10341539.009	15.711	658245.052				
	Huynh-Feldt	10341539.009	18.329	564218.088				
	Lower-bound	10341539.009	12.000	861794.917				

a. Computed using alpha =

Vertical Jump Repeated Measures ANOVA Pairwise Comparisons

Measure	(I) Condition	(J) Condition	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
						Lower Bound	Upper Bound
Height	1	2	-.026	.021	.726	-.086	.033
		3	-.007	.020	1.000	-.062	.049
	2	1	.026	.021	.726	-.033	.086
		3	.019	.020	1.000	-.037	.075
	3	1	.007	.020	1.000	-.049	.062
		2	-.019	.020	1.000	-.075	.037
Velocity	1	2	-.077*	.026	.040	-.150	-.003
		3	-.016	.015	.945	-.059	.027
	2	1	.077*	.026	.040	.003	.150
		3	.060	.025	.101	-.010	.130
	3	1	.016	.015	.945	-.027	.059
		2	-.060	.025	.101	-.130	.010
Power	1	2	-187.659*	56.539	.018	-344.806	-30.512
		3	-73.097	43.983	.367	-195.346	49.152

	2	1	187.659*	56.539	.018	30.512	344.806
		3	114.562	63.709	.292	-62.516	291.640
	3	1	73.097	43.983	.367	-49.152	195.346
		2	-114.562	63.709	.292	-291.640	62.516
Impulse	1	2	-.072*	.025	.039	-.141	-.003
		3	-.016	.015	.862	-.057	.024
	2	1	.072*	.025	.039	.003	.141
		3	.056	.023	.099	-.009	.120
	3	1	.016	.015	.862	-.024	.057
		2	-.056	.023	.099	-.120	.009
Force	1	2	40.235	215.665	1.000	-559.198	639.669
		3	-56.164	184.634	1.000	-569.348	457.021
	2	1	-40.235	215.665	1.000	-639.669	559.198
		3	-96.399	328.507	1.000	-1009.476	816.677
	3	1	56.164	184.634	1.000	-457.021	569.348
		2	96.399	328.507	1.000	-816.677	1009.476

Based on estimated marginal means

*. The mean difference is significant at the

b. Adjustment for multiple comparisons: Bonferroni.

Appendix 14 – Change of Direction SPSS Output
Descriptive Statistics

	Category	Mean	Std. Deviation	N
TimeINT	Sedentary	5.98667	.245981	6
	Trained	5.17125	.242454	8
	Total	5.52071	.479879	14
TimeEXT	Sedentary	5.77000	.318559	6
	Trained	5.11500	.212065	8
	Total	5.39571	.419995	14
TimeCONT	Sedentary	6.21333	.254454	6
	Trained	5.33875	.319349	8
	Total	5.71357	.530611	14
RFDPeakRINT	Sedentary	12347.91850	13841.150196	6
	Trained	8970.54550	8515.489914	8
	Total	10417.99107	10758.147831	14
RFDPeakREXT	Sedentary	14131.54688	7233.530080	6
	Trained	10456.36413	12236.179064	8
	Total	12031.44245	10213.105982	14
RFDPeakCONTR	Sedentary	13943.87297	12749.121215	6
	Trained	12326.42773	14657.534019	8
	Total	13019.61855	13374.985748	14
RFDtoHPeakRINT	Sedentary	12479.00250	10418.833982	6
	Trained	9185.67100	6589.204936	8
	Total	10597.09879	8245.606085	14
RFDHPeaktoPeakREXT	Sedentary	14752.64800	12133.424225	6
	Trained	6909.91863	12991.649132	8
	Total	10271.08836	12795.631779	14
RFDtoHPCONTR	Sedentary	14380.44850	14867.399365	6
	Trained	16980.86275	19396.782886	8
	Total	15866.39950	17011.373237	14
RFDHPeaktoPeakRINT	Sedentary	11784.12000	17342.870432	6
	Trained	8450.32650	12021.237323	8
	Total	9879.09514	14015.245980	14
RFDtoHPeakREXT	Sedentary	13112.69567	5196.295562	6
	Trained	13311.01688	11818.160122	8
	Total	13226.02207	9252.129272	14
RFDHpeaktoPeakCONTR	Sedentary	12526.16583	11986.394446	6
	Trained	7031.08800	9245.840505	8
	Total	9386.12136	10452.441593	14
NetImpulseRINT	Sedentary	110.60133	108.191481	6
	Trained	144.53988	66.209677	8
	Total	129.99479	84.654113	14
NetImpulseREXT	Sedentary	111.19850	95.127914	6
	Trained	138.00263	63.443139	8

	Total	126.51514	76.402335	14
NetImpulseCONTR	Sedentary	76.87067	70.647925	6
	Trained	109.63875	59.661805	8
	Total	95.59529	64.183500	14
ContactRINT	Sedentary	.48117	.114810	6
	Trained	.46763	.125785	8
	Total	.47343	.116780	14
ContactREXT	Sedentary	.46250	.159817	6
	Trained	.45438	.084385	8
	Total	.45786	.116942	14
ContactCONTR	Sedentary	.40717	.111272	6
	Trained	.45738	.158571	8
	Total	.43586	.137719	14
MaxForceRINT	Sedentary	880.10333	348.616382	6
	Trained	1017.17250	153.200743	8
	Total	958.42857	253.646640	14
MaxForceREXT	Sedentary	883.94333	340.995836	6
	Trained	953.55750	192.113750	8
	Total	923.72286	256.659002	14
MaxForceCONTR	Sedentary	825.24333	342.043263	6
	Trained	956.29875	250.037088	8
	Total	900.13214	288.428806	14
TimeMaxForceRINT	Sedentary	.15367	.119819	6
	Trained	.23875	.187466	8
	Total	.20229	.162340	14
TimeMaxForceREXT	Sedentary	.06883	.017348	6
	Trained	.20575	.132941	8
	Total	.14707	.120732	14
TimeMaxForceCONTR	Sedentary	.14317	.164546	6
	Trained	.16288	.095480	8
	Total	.15443	.124197	14
RFDPeakLINT	Sedentary	6023.43233	7825.028847	6
	Trained	23160.94513	30213.555189	8
	Total	15816.29679	24342.302276	14
RFDPeakLEXT	Sedentary	19085.40740	11834.682974	6
	Trained	16180.90117	18465.457272	8
	Total	17425.68956	15482.084823	14
RFDPeakCONTL	Sedentary	18137.45341	21412.074018	6
	Trained	32698.50175	47359.792542	8
	Total	26458.05246	37947.305657	14
RFDtoHPLINT	Sedentary	7277.23467	6601.431409	6
	Trained	27056.98525	33506.054676	8
	Total	18579.94929	26915.642634	14
RFDtoHPLEXT	Sedentary	23332.49117	15790.551989	6
	Trained	16607.41575	11781.122240	8

	Total	19489.59093	13511.631208	14
RFDtoHPCONTL	Sedentary	19435.18833	22384.228010	6
	Trained	32816.22350	46892.698190	8
	Total	27081.49414	37735.554796	14
RFDHPeaktoPeakLINT	Sedentary	4566.51233	9032.553799	6
	Trained	18666.93463	27234.201231	8
	Total	12623.89650	21981.674664	14
RFDHPeaktoPeakLEXT	Sedentary	13722.85867	9997.480446	6
	Trained	14938.60975	25429.873697	8
	Total	14417.57357	19673.420203	14
RFDHPeaktoPeakCONTL	Sedentary	15990.34283	20624.459465	6
	Trained	29701.68000	43086.302755	8
	Total	23825.39264	34825.302577	14
NetImpulseLINT	Sedentary	132.30167	44.638911	6
	Trained	130.39125	84.591237	8
	Total	131.21000	67.973647	14
NetImpulseLEXT	Sedentary	157.05400	59.142296	6
	Trained	134.39925	68.114542	8
	Total	144.10843	63.078622	14
NetImpulseCONTL	Sedentary	111.00967	71.270172	6
	Trained	107.32850	100.168539	8
	Total	108.90614	85.790353	14
ContactLINT	Sedentary	.48600	.095935	6
	Trained	.46350	.106507	8
	Total	.47314	.098902	14
ContactLEXT	Sedentary	.49200	.167126	6
	Trained	.48938	.087715	8
	Total	.49050	.122014	14
ContactCONTL	Sedentary	.41200	.070086	6
	Trained	.46288	.159756	8
	Total	.44107	.127728	14
MaxForceLINT	Sedentary	862.14500	181.920931	6
	Trained	1092.93500	426.645521	8
	Total	994.02500	353.257418	14
MexForceLEXT	Sedentary	1014.36833	192.475780	6
	Trained	953.96125	437.707985	8
	Total	979.85000	344.055396	14
MaxForceCONTL	Sedentary	953.74500	397.445105	6
	Trained	1034.60125	432.543293	8
	Total	999.94857	404.007240	14
TimeMaxForceLINT	Sedentary	.28667	.161417	6
	Trained	.14275	.116723	8
	Total	.20443	.151063	14
TimeMaxForceLEXT	Sedentary	.08333	.071397	6
	Trained	.14338	.114373	8

	Total	.11764	.099775	14
TimeMaxForceCONTL	Sedentary	.15133	.128341	6
	Trained	.11763	.087761	8
	Total	.13207	.103837	14

Change of Direction Repeated Measures ANOVA – Univariate Tests

Source	Measure		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Condition	Time	Sphericity Assumed	.771	2	.386	13.290	.000	.526
		Greenhouse-Geisser	.771	1.757	.439	13.290	.000	.526
		Huynh-Feldt	.771	2.000	.386	13.290	.000	.526
		Lower-bound	.771	1.000	.771	13.290	.003	.526
	RDFPeakR	Sphericity Assumed	43474749.132	2	21737374.566	.198	.822	.016
		Greenhouse-Geisser	43474749.132	1.371	31719782.053	.198	.739	.016
		Huynh-Feldt	43474749.132	1.617	26885317.037	.198	.776	.016
		Lower-bound	43474749.132	1.000	43474749.132	.198	.664	.016
	RFDtoHPR	Sphericity Assumed	214960497.594	2	107480248.797	.692	.510	.055
		Greenhouse-Geisser	214960497.594	1.579	136146477.565	.692	.480	.055
		Huynh-Feldt	214960497.594	1.929	111424259.645	.692	.506	.055
		Lower-bound	214960497.594	1.000	214960497.594	.692	.422	.055
	RFDHPtoPR	Sphericity Assumed	98187267.698	2	49093633.849	.491	.618	.039
		Greenhouse-Geisser	98187267.698	1.283	76558534.584	.491	.540	.039
		Huynh-Feldt	98187267.698	1.489	65954835.729	.491	.566	.039
		Lower-bound	98187267.698	1.000	98187267.698	.491	.497	.039

	ImpulseR	Sphericity Assumed	9915.266	2	4957.633	5.459	.011	.313
		Greenhouse-Geisser	9915.266	1.573	6301.572	5.459	.019	.313
		Huynh-Feldt	9915.266	1.921	5161.759	5.459	.012	.313
		Lower-bound	9915.266	1.000	9915.266	5.459	.038	.313
	ContactR	Sphericity Assumed	.012	2	.006	1.055	.364	.081
		Greenhouse-Geisser	.012	1.294	.010	1.055	.341	.081
		Huynh-Feldt	.012	1.505	.008	1.055	.349	.081
		Lower-bound	.012	1.000	.012	1.055	.325	.081
	MaxForceR	Sphericity Assumed	22969.981	2	11484.990	.544	.587	.043
		Greenhouse-Geisser	22969.981	1.235	18606.340	.544	.508	.043
		Huynh-Feldt	22969.981	1.420	16179.888	.544	.531	.043
		Lower-bound	22969.981	1.000	22969.981	.544	.475	.043
	TimeMaxForceR	Sphericity Assumed	.026	2	.013	.704	.505	.055
		Greenhouse-Geisser	.026	1.467	.017	.704	.466	.055
		Huynh-Feldt	.026	1.759	.015	.704	.489	.055
		Lower-bound	.026	1.000	.026	.704	.418	.055
	RFDPeakL	Sphericity Assumed	855079540.129	2	427539770.064	1.288	.294	.097

	Greenhouse-Geisser	855079540.129	1.274	671272544.249	1.288	.286	.097
	Huynh-Feldt	855079540.129	1.476	579262956.885	1.288	.290	.097
	Lower-bound	855079540.129	1.000	855079540.129	1.288	.279	.097
RFDtpHPL	Sphericity Assumed	576025881.410	2	288012940.705	.800	.461	.062
	Greenhouse-Geisser	576025881.410	1.452	396734018.355	.800	.428	.062
	Huynh-Feldt	576025881.410	1.737	331533211.017	.800	.447	.062
	Lower-bound	576025881.410	1.000	576025881.410	.800	.389	.062
RFDHPtoPL	Sphericity Assumed	941589521.171	2	470794760.585	1.615	.220	.119
	Greenhouse-Geisser	941589521.171	1.209	778915096.485	1.615	.228	.119
	Huynh-Feldt	941589521.171	1.383	680844857.073	1.615	.227	.119
	Lower-bound	941589521.171	1.000	941589521.171	1.615	.228	.119
ImpulseL	Sphericity Assumed	9303.218	2	4651.609	2.336	.118	.163
	Greenhouse-Geisser	9303.218	1.904	4886.666	2.336	.121	.163
	Huynh-Feldt	9303.218	2.000	4651.609	2.336	.118	.163
	Lower-bound	9303.218	1.000	9303.218	2.336	.152	.163
ContactL	Sphericity Assumed	.020	2	.010	1.031	.372	.079
	Greenhouse-Geisser	.020	1.981	.010	1.031	.372	.079
	Huynh-Feldt	.020	2.000	.010	1.031	.372	.079

		Lower-bound	.020	1.000	.020	1.031	.330	.079
	MaxForceL	Sphericity Assumed	1923.271	2	961.635	.019	.981	.002
		Greenhouse-Geisser	1923.271	1.787	1076.518	.019	.973	.002
		Huynh-Feldt	1923.271	2.000	961.635	.019	.981	.002
		Lower-bound	1923.271	1.000	1923.271	.019	.892	.002
	TimeMaxForceL	Sphericity Assumed	.078	2	.039	4.519	.022	.274
		Greenhouse-Geisser	.078	1.633	.048	4.519	.030	.274
		Huynh-Feldt	.078	2.000	.039	4.519	.022	.274
		Lower-bound	.078	1.000	.078	4.519	.055	.274
	Time	Sphericity Assumed	.089	2	.044	1.525	.238	.113
		Greenhouse-Geisser	.089	1.757	.050	1.525	.240	.113
		Huynh-Feldt	.089	2.000	.044	1.525	.238	.113
		Lower-bound	.089	1.000	.089	1.525	.240	.113
Condition * Category	RDFPeakR	Sphericity Assumed	8480365.831	2	4240182.915	.039	.962	.003
		Greenhouse-Geisser	8480365.831	1.371	6187392.941	.039	.911	.003
		Huynh-Feldt	8480365.831	1.617	5244362.038	.039	.937	.003
		Lower-bound	8480365.831	1.000	8480365.831	.039	.848	.003
	RFDtoHPR	Sphericity Assumed	187991438.586	2	93995719.293	.605	.554	.048

	Greenhouse-Geisser	187991438.586	1.579	119065467.667	.605	.519	.048
	Huynh-Feldt	187991438.586	1.929	97444912.431	.605	.549	.048
	Lower-bound	187991438.586	1.000	187991438.586	.605	.452	.048
RFDHPtoPR	Sphericity Assumed	56642030.777	2	28321015.389	.283	.756	.023
	Greenhouse-Geisser	56642030.777	1.283	44164900.133	.283	.659	.023
	Huynh-Feldt	56642030.777	1.489	38047864.279	.283	.692	.023
	Lower-bound	56642030.777	1.000	56642030.777	.283	.604	.023
ImpulseR	Sphericity Assumed	100.387	2	50.194	.055	.946	.005
	Greenhouse-Geisser	100.387	1.573	63.800	.055	.911	.005
	Huynh-Feldt	100.387	1.921	52.260	.055	.941	.005
	Lower-bound	100.387	1.000	100.387	.055	.818	.005
ContactR	Sphericity Assumed	.009	2	.004	.729	.493	.057
	Greenhouse-Geisser	.009	1.294	.007	.729	.441	.057
	Huynh-Feldt	.009	1.505	.006	.729	.459	.057
	Lower-bound	.009	1.000	.009	.729	.410	.057
MaxForceR	Sphericity Assumed	9555.851	2	4777.925	.227	.799	.019
	Greenhouse-Geisser	9555.851	1.235	7740.512	.227	.692	.019
	Huynh-Feldt	9555.851	1.420	6731.072	.227	.724	.019
	Lower-bound	9555.851	1.000	9555.851	.227	.643	.019
TimeMaxForceR	Sphericity Assumed	.024	2	.012	.652	.530	.052

	Greenhouse-Geisser	.024	1.467	.016	.652	.487	.052
	Huynh-Feldt	.024	1.759	.013	.652	.512	.052
	Lower-bound	.024	1.000	.024	.652	.435	.052
RFDPeakL	Sphericity Assumed	815275761.940	2	407637880.970	1.228	.311	.093
	Greenhouse-Geisser	815275761.940	1.274	640024944.228	1.228	.299	.093
	Huynh-Feldt	815275761.940	1.476	552298384.390	1.228	.304	.093
	Lower-bound	815275761.940	1.000	815275761.940	1.228	.290	.093
RFDtpHPL	Sphericity Assumed	1311662906.358	2	655831453.179	1.821	.183	.132
	Greenhouse-Geisser	1311662906.358	1.452	903399156.811	1.821	.195	.132
	Huynh-Feldt	1311662906.358	1.737	754931035.481	1.821	.189	.132
	Lower-bound	1311662906.358	1.000	1311662906.358	1.821	.202	.132
RFDHPtoPL	Sphericity Assumed	368349498.226	2	184174749.113	.632	.540	.050
	Greenhouse-Geisser	368349498.226	1.209	304711318.998	.632	.469	.050
	Huynh-Feldt	368349498.226	1.383	266346274.925	.632	.488	.050
	Lower-bound	368349498.226	1.000	368349498.226	.632	.442	.050
ImpulseL	Sphericity Assumed	906.811	2	453.406	.228	.798	.019
	Greenhouse-Geisser	906.811	1.904	476.317	.228	.788	.019
	Huynh-Feldt	906.811	2.000	453.406	.228	.798	.019
	Lower-bound	906.811	1.000	906.811	.228	.642	.019

	ContactL	Sphericity Assumed	.010	2	.005	.497	.615	.040
		Greenhouse-Geisser	.010	1.981	.005	.497	.613	.040
		Huynh-Feldt	.010	2.000	.005	.497	.615	.040
		Lower-bound	.010	1.000	.010	.497	.494	.040
	MaxForceL	Sphericity Assumed	145407.086	2	72703.543	1.446	.255	.108
		Greenhouse-Geisser	145407.086	1.787	81389.123	1.446	.257	.108
		Huynh-Feldt	145407.086	2.000	72703.543	1.446	.255	.108
		Lower-bound	145407.086	1.000	145407.086	1.446	.252	.108
	TimeMaxForceL	Sphericity Assumed	.071	2	.036	4.118	.029	.255
		Greenhouse-Geisser	.071	1.633	.044	4.118	.039	.255
		Huynh-Feldt	.071	2.000	.036	4.118	.029	.255
		Lower-bound	.071	1.000	.071	4.118	.065	.255
Error(Condition)	Time	Sphericity Assumed	.696	24	.029			
		Greenhouse-Geisser	.696	21.080	.033			
		Huynh-Feldt	.696	24.000	.029			
		Lower-bound	.696	12.000	.058			
	RDFPeakR	Sphericity Assumed	2638795920.933	24	109949830.039			
		Greenhouse-Geisser	2638795920.933	16.447	160441852.580			
		Huynh-Feldt	2638795920.933	19.405	135988641.577			

	Lower-bound	2638795920.933	12.000	219899660.078			
RFDtoHPR	Sphericity Assumed	3726151341.652	24	155256305.902			
	Greenhouse-Geisser	3726151341.652	18.947	196664963.144			
	Huynh-Feldt	3726151341.652	23.150	160953469.442			
	Lower-bound	3726151341.652	12.000	310512611.804			
RFDHPtoPR	Sphericity Assumed	2401327109.164	24	100055296.215			
	Greenhouse-Geisser	2401327109.164	15.390	156030145.970			
	Huynh-Feldt	2401327109.164	17.864	134419274.116			
	Lower-bound	2401327109.164	12.000	200110592.430			
ImpulseR	Sphericity Assumed	21794.108	24	908.088			
	Greenhouse-Geisser	21794.108	18.882	1154.257			
	Huynh-Feldt	21794.108	23.051	945.478			
	Lower-bound	21794.108	12.000	1816.176			
ContactR	Sphericity Assumed	.141	24	.006			
	Greenhouse-Geisser	.141	15.523	.009			
	Huynh-Feldt	.141	18.057	.008			
	Lower-bound	.141	12.000	.012			
MaxForceR	Sphericity Assumed	506258.195	24	21094.091			

	Greenhouse-Geisser	506258.195	14.814	34173.632			
	Huynh-Feldt	506258.195	17.036	29717.051			
	Lower-bound	506258.195	12.000	42188.183			
TimeMaxForceR	Sphericity Assumed	.435	24	.018			
	Greenhouse-Geisser	.435	17.598	.025			
	Huynh-Feldt	.435	21.111	.021			
	Lower-bound	.435	12.000	.036			
RFDPeakL	Sphericity Assumed	7967395259.928	24	331974802.497			
	Greenhouse-Geisser	7967395259.928	15.286	521227698.338			
	Huynh-Feldt	7967395259.928	17.714	449784369.011			
	Lower-bound	7967395259.928	12.000	663949604.994			
RFDtpHPL	Sphericity Assumed	8642693435.532	24	360112226.481			
	Greenhouse-Geisser	8642693435.532	17.423	496049831.375			
	Huynh-Feldt	8642693435.532	20.850	414527078.121			
	Lower-bound	8642693435.532	12.000	720224452.961			
RFDHPtoPL	Sphericity Assumed	6994830592.255	24	291451274.677			
	Greenhouse-Geisser	6994830592.255	14.506	482196950.225			
	Huynh-Feldt	6994830592.255	16.596	421485364.885			

		Lower-bound	6994830592.255	12.000	582902549.355			
	ImpulseL	Sphericity Assumed	47786.042	24	1991.085			
		Greenhouse-Geisser	47786.042	22.846	2091.699			
		Huynh-Feldt	47786.042	24.000	1991.085			
		Lower-bound	47786.042	12.000	3982.170			
	ContactL	Sphericity Assumed	.239	24	.010			
		Greenhouse-Geisser	.239	23.774	.010			
		Huynh-Feldt	.239	24.000	.010			
		Lower-bound	.239	12.000	.020			
	MaxForceL	Sphericity Assumed	1206981.433	24	50290.893			
		Greenhouse-Geisser	1206981.433	21.439	56298.930			
		Huynh-Feldt	1206981.433	24.000	50290.893			
		Lower-bound	1206981.433	12.000	100581.786			
	TimeMaxForceL	Sphericity Assumed	.208	24	.009			
		Greenhouse-Geisser	.208	19.594	.011			
		Huynh-Feldt	.208	24.000	.009			
		Lower-bound	.208	12.000	.017			

Change of Direction Repeated Measures ANOVA Pairwise Comparisons

Measure	(I) Condition	(J) Condition	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
						Lower Bound	Upper Bound
Time	1	2	.136	.058	.106	-.024	.296
		3	-.197	.076	.071	-.409	.015
	2	1	-.136	.058	.106	-.296	.024
		3	-.334*	.060	.000	-.500	-.167
	3	1	.197	.076	.071	-.015	.409
		2	.334*	.060	.000	.167	.500
RDFPeakR	1	2	-1634.724	3782.974	1.000	-12149.398	8879.951
		3	-2475.918	5117.333	1.000	-16699.408	11747.571
	2	1	1634.724	3782.974	1.000	-8879.951	12149.398
		3	-841.195	2757.728	1.000	-8506.224	6823.835
	3	1	2475.918	5117.333	1.000	-11747.571	16699.408
		2	841.195	2757.728	1.000	-6823.835	8506.224
RFDtoHPR	1	2	1.053	4050.043	1.000	-11255.932	11258.039
		3	-4848.319	5858.805	1.000	-21132.710	11436.073
	2	1	-1.053	4050.043	1.000	-11258.039	11255.932
		3	-4849.372	4146.829	.795	-16375.371	6676.626
	3	1	4848.319	5858.805	1.000	-11436.073	21132.710
		2	4849.372	4146.829	.795	-6676.626	16375.371
RFDHPtoPR	1	2	-3094.633	4083.748	1.000	-14445.302	8256.036
		3	338.596	4777.654	1.000	-12940.765	13617.958
	2	1	3094.633	4083.748	1.000	-8256.036	14445.302
		3	3433.229	2066.691	.368	-2311.082	9177.541
	3	1	-338.596	4777.654	1.000	-13617.958	12940.765
		2	-3433.229	2066.691	.368	-9177.541	2311.082
ImpulseR	1	2	2.970	10.402	1.000	-25.942	31.882

		3	34.316*	9.415	.010	8.148	60.484
	2	1	-2.970	10.402	1.000	-31.882	25.942
		3	31.346	14.158	.141	-8.006	70.698
	3	1	-34.316*	9.415	.010	-60.484	-8.148
		2	-31.346	14.158	.141	-70.698	8.006
ContactR	1	2	.016	.030	1.000	-.067	.099
		3	.042	.017	.087	-.005	.089
	2	1	-.016	.030	1.000	-.099	.067
		3	.026	.037	1.000	-.077	.130
	3	1	-.042	.017	.087	-.089	.005
		2	-.026	.037	1.000	-.130	.077
MaxForceR	1	2	29.888	35.822	1.000	-69.680	129.455
		3	57.867	73.371	1.000	-146.065	261.799
	2	1	-29.888	35.822	1.000	-129.455	69.680
		3	27.979	50.618	1.000	-112.711	168.670
	3	1	-57.867	73.371	1.000	-261.799	146.065
		2	-27.979	50.618	1.000	-168.670	112.711
TimeMaxForceR	1	2	.059	.055	.903	-.093	.210
		3	.043	.062	1.000	-.129	.215
	2	1	-.059	.055	.903	-.210	.093
		3	-.016	.034	1.000	-.109	.078
	3	1	-.043	.062	1.000	-.215	.129
		2	.016	.034	1.000	-.078	.109
RFDPeakL	1	2	-3040.966	4345.264	1.000	-15118.511	9036.580
		3	-10825.789	6672.562	.392	-29371.995	7720.418
	2	1	3040.966	4345.264	1.000	-9036.580	15118.511
		3	-7784.823	9046.246	1.000	-32928.621	17358.975
	3	1	10825.789	6672.562	.392	-7720.418	29371.995
		2	7784.823	9046.246	1.000	-17358.975	32928.621
RFDtpHPL	1	2	-2802.844	6163.777	1.000	-19934.895	14329.208

		3	-8958.596	5901.387	.465	-25361.342	7444.150
	2	1	2802.844	6163.777	1.000	-14329.208	19934.895
		3	-6155.752	9204.922	1.000	-31740.585	19429.080
	3	1	8958.596	5901.387	.465	-7444.150	25361.342
		2	6155.752	9204.922	1.000	-19429.080	31740.585
RFDHPtoPL	1	2	-2714.011	3414.712	1.000	-12205.112	6777.090
		3	-11229.288	6690.419	.357	-29825.127	7366.551
	2	1	2714.011	3414.712	1.000	-6777.090	12205.112
		3	-8515.277	8431.368	.997	-31950.038	14919.484
	3	1	11229.288	6690.419	.357	-7366.551	29825.127
		2	8515.277	8431.368	.997	-14919.484	31950.038
ImpulseL	1	2	-14.380	15.339	1.000	-57.014	28.253
		3	22.177	18.661	.773	-29.690	74.045
	2	1	14.380	15.339	1.000	-28.253	57.014
		3	36.558	16.959	.156	-10.578	83.693
	3	1	-22.177	18.661	.773	-74.045	29.690
		2	-36.558	16.959	.156	-83.693	10.578
ContactL	1	2	-.016	.040	1.000	-.127	.095
		3	.037	.037	.986	-.065	.139
	2	1	.016	.040	1.000	-.095	.127
		3	.053	.038	.551	-.052	.158
	3	1	-.037	.037	.986	-.139	.065
		2	-.053	.038	.551	-.158	.052
MaxForceL	1	2	-6.625	88.488	1.000	-252.576	239.326
		3	-16.633	70.236	1.000	-211.854	178.587
	2	1	6.625	88.488	1.000	-239.326	252.576
		3	-10.008	96.119	1.000	-277.169	257.152
	3	1	16.633	70.236	1.000	-178.587	211.854
		2	10.008	96.119	1.000	-257.152	277.169

TimeMaxForce L	1	2	.101*	.034	.035	.007	.196
		3	.080	.043	.255	-.039	.199
	2	1	-.101*	.034	.035	-.196	-.007
		3	-.021	.028	1.000	-.100	.058
	3	1	-.080	.043	.255	-.199	.039
		2	.021	.028	1.000	-.058	.100

Based on estimated marginal means

*. The mean difference is significant at the

b. Adjustment for multiple comparisons: Bonferroni.

Change of Direction Repeated Measures ANOVA – Confidence Intervals Category * Condition

Measure	Category	Condition	Mean	Std. Error	95% Confidence Interval	
					Lower Bound	Upper Bound
Time	Sedentary	1	5.987	.100	5.770	6.204
		2	5.770	.107	5.537	6.003
		3	6.213	.120	5.952	6.475
	Trained	1	5.171	.086	4.983	5.359
		2	5.115	.093	4.913	5.317
		3	5.339	.104	5.112	5.565
RDFPeakR	Sedentary	1	12347.919	4511.532	2518.135	22177.702
		2	14131.547	4264.987	4838.938	23424.156
		3	13943.873	5672.306	1584.981	26302.765
	Trained	1	8970.546	3907.101	457.703	17483.388
		2	10456.364	3693.587	2408.729	18503.999
		3	12326.428	4912.361	1623.313	23029.542
RFDtoHPR	Sedentary	1	12479.002	3429.212	5007.390	19950.615
		2	14752.648	5160.723	3508.398	25996.898
		3	14380.448	7206.136	-1320.372	30081.269
	Trained	1	9185.671	2969.785	2715.065	15656.277
		2	6909.919	4469.317	-2827.887	16647.725
		3	16980.863	6240.697	3383.553	30578.172
RFDHPtoPR	Sedentary	1	11784.120	5910.733	-1094.260	24662.500
		2	13112.696	3931.161	4547.432	21677.959
		3	12526.166	4276.498	3208.477	21843.854
	Trained	1	8450.327	5118.845	-2702.678	19603.331
		2	13311.017	3404.485	5893.281	20728.753
		3	7031.088	3703.556	-1038.267	15100.443
ImpulseR	Sedentary	1	110.601	35.200	33.906	187.296
		2	111.199	31.933	41.621	180.776

		3	76.871	26.319	19.527	134.214
		1	144.540	30.484	78.120	210.960
	Trained	2	138.003	27.655	77.747	198.258
		3	109.639	22.793	59.978	159.300
ContactR	Sedentary	1	.481	.050	.373	.589
		2	.463	.050	.354	.571
		3	.407	.057	.282	.532
	Trained	1	.468	.043	.374	.561
		2	.454	.043	.361	.548
		3	.457	.050	.349	.566
MaxForceR	Sedentary	1	880.103	103.545	654.497	1105.710
		2	883.943	107.996	648.640	1119.246
		3	825.243	119.175	565.583	1084.904
	Trained	1	1017.173	89.673	821.792	1212.553
		2	953.557	93.527	749.779	1157.336
		3	956.299	103.209	731.426	1181.171
TimeMaxForceR	Sedentary	1	.154	.066	.009	.298
		2	.069	.042	-.022	.160
		3	.143	.053	.029	.258
	Trained	1	.239	.058	.113	.364
		2	.206	.036	.127	.284
		3	.163	.046	.064	.262
RFDPeakL	Sedentary	1	6023.432	9643.772	-14988.541	27035.406
		2	19085.407	6548.018	4818.503	33352.312
		3	18137.453	15808.329	-16305.936	52580.843
	Trained	1	23160.945	8351.751	4964.042	41357.848
		2	16180.901	5670.750	3825.399	28536.403
		3	32698.502	13690.414	2869.652	62527.352
RFDtpHPL	Sedentary	1	7277.235	10591.194	-15798.995	30353.464
		2	23332.491	5550.615	11238.740	35426.242

		3	19435.188	15766.413	-14916.875	53787.251
		1	27056.985	9172.243	7072.384	47041.586
	Trained	2	16607.416	4806.974	6133.920	27080.912
		3	32816.224	13654.114	3066.464	62565.983
		1	4566.512	8819.051	-14648.548	23781.573
	Sedentary	2	13722.859	8355.385	-4481.962	31927.679
		3	15990.343	14492.262	-15585.584	47566.270
RFDHPtoPL		1	18666.935	7637.522	2026.204	35307.665
	Trained	2	14938.610	7235.976	-827.227	30704.447
		3	29701.680	12550.667	2356.125	57047.235
		1	132.302	28.880	69.377	195.226
	Sedentary	2	157.054	26.343	99.657	214.451
		3	111.010	36.445	31.603	190.417
ImpulseL		1	130.391	25.011	75.897	184.886
	Trained	2	134.399	22.814	84.692	184.107
		3	107.329	31.562	38.560	176.097
		1	.486	.042	.395	.577
	Sedentary	2	.492	.052	.379	.605
		3	.412	.053	.296	.528
ContactL		1	.464	.036	.385	.542
	Trained	2	.489	.045	.392	.587
		3	.463	.046	.363	.563
		1	862.145	141.405	554.051	1170.239
	Sedentary	2	1014.368	145.600	697.133	1331.603
		3	953.745	170.761	581.689	1325.801
MaxForceL		1	1092.935	122.460	826.117	1359.753
	Trained	2	953.961	126.093	679.228	1228.695
		3	1034.601	147.883	712.391	1356.811
TimeMaxForceL	Sedentary	1	.287	.056	.165	.409

		2	.083	.040	-.005	.171
		3	.151	.044	.057	.246
		1	.143	.048	.037	.248
	Trained	2	.143	.035	.067	.219
		3	.118	.038	.036	.200

Appendix 15 SPSS Output – Chi Square Test – Focus Preferences Vertical Jump

Case Processing Summary

	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
Category * VJFocus	42	75.0%	14	25.0%	56	100.0%

Category * VJFocus Crosstabulation

			VJFocus			Total
			INT	EXT	NEUTRAL	
Category	SEDENTARY	Count	13	1	4	18
		Expected Count	10.7	.4	6.9	18.0
	TRAINED	Count	12	0	12	24
		Expected Count	14.3	.6	9.1	24.0
Total		Count	25	1	16	42
		Expected Count	25.0	1.0	16.0	42.0

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	4.270[a]	2	.118
Likelihood Ratio	4.752	2	.093
Linear-by-Linear Association	2.698	1	.100
N of Valid Cases	42		

a. 2 cells (33.3%) have expected count less than 5. The minimum expected count is .43.

Symmetric Measures

		Value	Approx. Sig.
Nominal by Nominal	Phi	.319	.118
	Cramer's V	.319	.118
N of Valid Cases		42	

Appendix 16 - Chi Square Test – Focus Preferences Change of Direction

Case Processing Summary

	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
Category * CoDFocus	56	100.0%	0	0.0%	56	100.0%

Category * CoDFocus Crosstabulation

			CoDFocus			Total
			INT	EXT	NEUTRAL	
Category	SEDENTARY	Count	7	0	17	24
		Expected Count	5.6	.9	17.6	24.0
	TRAINED	Count	6	2	24	32
		Expected Count	7.4	1.1	23.4	32.0
Total		Count	13	2	41	56
		Expected Count	13.0	2.0	41.0	56.0

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	2.174[a]	2	.337
Likelihood Ratio	2.904	2	.234
Linear-by-Linear Association	.401	1	.527
N of Valid Cases	56		

a. 2 cells (33.3%) have expected count less than 5. The minimum expected count is .86.

Symmetric Measures

		Value	Approx. Sig.
Nominal by Nominal	Phi	.197	.337
	Cramer's V	.197	.337
N of Valid Cases		56	

Appendix 17 – Signed Ethics Application

St Mary's University Twickenham London

St Mary's Ethics Application Checklist
The checklist below will help you to ensure that all the supporting documents are submitted with your ethics application form. The supporting documents are necessary for the Ethics Sub-Committee to be able to review and approve your application.

Please note, if the appropriate documents are not submitted with the application form then the application will be returned directly to the applicant and may need to be re-submitted at a later date.

	Enclosed? (delete as appropriate)		Version No
Document	Yes	Not applicable	
1.Application Form	Mandatory		
2.Risk Assessment Form	Yes		
3.Participant Invitation Letter	Yes		
4.Participant Information Sheet	Mandatory		
5.Participant Consent Form	Mandatory		
6.Parental Consent Form		N/A	
7.Participant Recruitment Material - e.g. copies of Posters, newspaper adverts, website, emails	Yes		
8.Letter from host organisation (granting permission to conduct the study on the premises)	Yes		
9. Research instrument, e.g. validated questionnaire, survey, interview schedule	Yes		
10.DBS included		N/A	
11.Other Research Ethics Committee application (e.g. NHS REC form)		N/A	

I can confirm that all relevant documents are included in order of the list and in one PDF document entitled with you: ***Full Name, School, Supervisor.***

Signature of Applicant:

Signature of Supervisor:

Research Ethics Application Comments Form

Level:	2
Type:	Postgraduate
Proposer:	Ewan Birnie
Supervisor:	Daniel Cleather
School:	SHAS
Programme:	Strength and Conditioning MSc
Title:	Testing the constrained action hypothesis – the impact of internal and external cues on vertical jump and change of direction performance in trained and sedentary populations.
Date:	27/01/16
Review No.:	1

Comments (number corresponds to relevant section on Ethics Application Form)
No amendments required

Impression/Decision
Approved, proceed with research.

Dr Jessica Hill
Ethics Representative.
School of Sport, Health and Applied Science.
St Mary's University.

St Mary's University Twickenham London

Approval Sheet

Name of applicant: Ewan Birnie

Name of supervisor: Dr Dan Cleather

Programme of study: MSc Strength and Conditioning

Title of project: Testing the constrained action hypothesis – the impact of internal and external cues on vertical jump and change of direction and performance in trained and sedentary populations.

Supervisors, please complete section 1 or 2. If approved at level 1, please forward a copy of this Approval Sheet to the School Ethics Representative for their records.

SECTION 1

Approved at Level 1

Signature of supervisor (for student applications

Date: 22/1/16

SECTION 2

Refer to School Ethics Representative for consideration at Level 2 or Level 3

Signature of supervisor...